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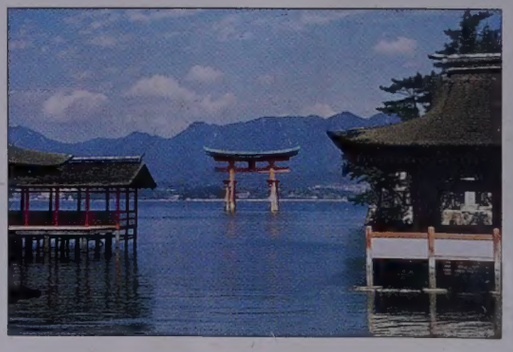

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JANUARY 1992

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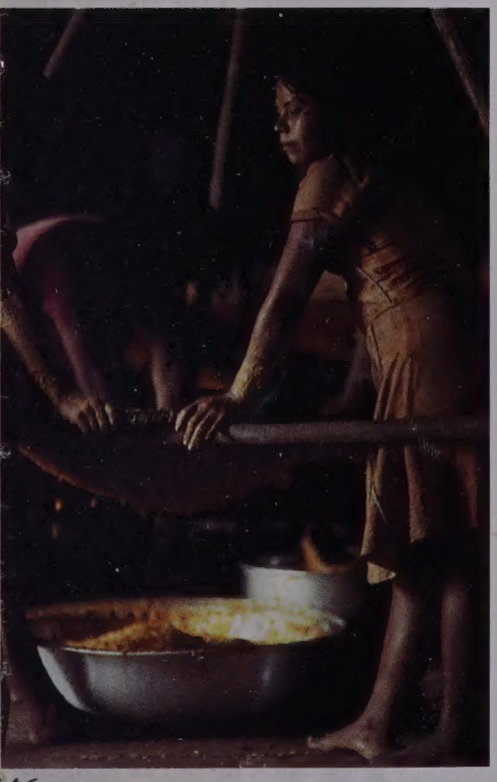

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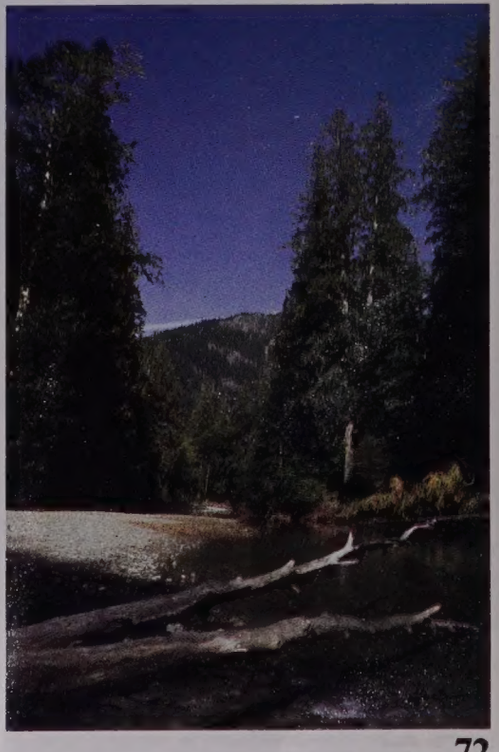

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NATURAL HISTORY (ISSN 0028-0712) is published monthly by the American Museum of Natural History, Central Park West at 79th Street, New York, N.Y. 10024. Subscriptions: $25.00 a year. In Canada and all other countries: $34.00 a year. Second-class postage paid at New York, N.Y., and at additional mailing offices. Copyright © 1991 by American Museum of Natural History. All rights reserved. No part of this periodical may be reproduced without written consent of *Natural History*. Send subscription orders and undeliverable copies to the address below. Membership and subscription information: Write to address below or call (800) 234-5252 if urgent. POSTMASTER: Send address changes to Natural History, Post Office Box 5000, Harlan, IA 51537-5000.

Cultivating a Killer Virus

In Southeast Asia, fish farming may inadvertently spawn new and potentially lethal strains of influenza

by Christoph Scholtissek

Since ancient times, Southeast Asia has been heavily populated, forcing farmers to develop methods of squeezing the most food from the available land. Foreigners passing through China, for instance, marvel at the impressive terraces carved into the mountains to grow rice. Many other age-old agricultural practices, however, go unnoticed. One is the fish pond, around which humans live in proximity with pigs and poultry. Waste from animals, as well as from people, provides all the fertilizer needed to grow water hyacinths, grasses, and algae in the fish pond. What might seem like pollution to us is a rich resource that can be turned into plant food for an abundant harvest of fish. Because of their ravenous appetites and resistance to disease, carp are perfectly suited to such ponds. Various carp species feed at different levels in the pond, often consuming as much as 100 percent of their body weight in plants each day. Mud carp even sift through the material on the bottom for bacteria and protozoans on which to feed.

This sort of aquaculture is now being investigated by scientists who believe it can be exported to underdeveloped countries to provide fish, a rich source of protein, to their populations. When my friend Ernest Naylor, of the Marine Biological Institute of the University of Wales, told me he was involved in this enterprise, known as the Blue Revolution, I told him about my work on the evolution of lethal strains of influenza viruses and how farming practices in Southeast Asia create the ideal environment for their propagation. The fish themselves play no role in the process, but the fish ponds bring humans and ducks into contact with pigs—and pigs are the one animal that can serve as a "mixing vessel" for the creation of new influenza viruses that may threaten world health. What I had to explain to my friend, I will repeat here.

In this century, all serious outbreaks of influenza have originated in Southeast Asia. In the winter of 1918–19, an influenza pandemic killed about 550,000 people in the United States and some 20 million worldwide. Nowadays, such pandemics can still sweep around the globe in a single winter season and remain a very real threat. Affecting mainly the respiratory tract, the influenza virus is rapidly passed from person to person by a cough, sneeze, or handshake. (The disease further weakens people with chronic heart and lung diseases, and even in an average flu season, as many as 20,000 people in the United States succumb to the infections of bacterial pneumonia that follow.) Because there is reason to assume that such severe pandemics will happen again, my colleagues and I at the University of Giessen in Germany have traced the evolutionary pathways by which new strains, partly derived from animal influenza viruses, suddenly arise.

Each type of virus has evolved its own strategy to survive and multiply in a hostile environment, but influenza viruses are the grand masters. Vaccines are of limited use against them because of their remarkable ability to constantly change their coat. The surface of the influenza virus bristles with two kinds of protein molecules, about 500 hemagglutinin and about 100 neuraminidase molecules per particle. These molecules, known as antigens, allow the virus to attach to the protective membrane of the host's cells and break into their interior. Once in, the genetic material of the virus takes control of the cell's machinery and directs it to churn out more viruses, damaging or killing the cell in the process. The antigens, however, also betray the presence of the virus to the host's immune system, which produces antibodies that recognize and mark the invader for destruction. Without prior exposure to the specific virus's antigens, however, the host lacks antibodies that recognize the virus and is susceptible to infection. Because the influenza viruses constantly change their antigenic coats, we may be confronted with new strains for which we have no antibodies. Thus, influenza is a perennial threat.

The antigens on the surface of the influenza virus can change in two ways. Ran-

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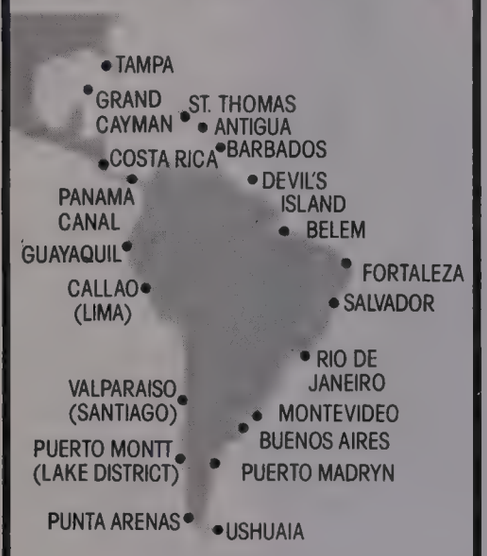

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dom mutations—or genetic "drift"—may produce subtle, but nevertheless significant, changes in the antigenic coat. But if the host has antibodies to the original virus, they usually confer some resistance. The real threat lies in a sudden "antigenic shift," when a virus picks up one or more genes, including the hemagglutinin gene, from an animal influenza virus. These new genes can replace the original ones, producing a new strain with an entirely new antigenic coat for which humans may have no immunity. This mixing of genetic material occurs readily between influenza viruses because of the unique arrangement of their genes. Unlike that of most other viruses, the single-stranded RNA of the influenza virus is segmented. The eight pieces, each defining a gene of the virus, can be reshuffled when two different strains infect the same host cell. This total of sixteen gene segments can recombine in 254 possible ways.

The last time such a shift occurred was in 1968, when the appearance of the Hong Kong virus (named for the location where it was first isolated) caused a pandemic. Seven of its RNA segments came from the prevailing, relatively benign human virus, but the remaining segment, the hemagglutinin gene, was contributed by an avian influenza virus. Of the three distinct types of influenza viruses affecting humans (types A, B, and C), type A is the only one that can change its coat in this way. Thus, all major recent pandemics, including that caused by the Hong Kong virus, resulted from an antigenic shift of type A, which happens roughly every ten to twenty years.

Influenza A viruses change because they are the only type that persists in both animal and human populations. If a particularly virulent strain of influenza manages to eliminate its host population, it is bound to die out (which seems to happen with highly pathogenic chicken and seal influenza viruses), but large reservoirs of nonlethal influenza viruses persist in waterfowl and humans. Virologist Robert Webster and his colleagues at Saint Jude Children's Research Hospital in Memphis found that duck influenza viruses live and multiply only in the birds' intestinal tracts, causing little harm and eliciting only a meager immune response. For this reason ducks harbor a remarkable number of influenza strains, which are easily spread through the water from one duck to another and distributed worldwide along their flight paths. But avian influenza viruses do not spread in the human population and vice versa. So how do two genetically independent reservoirs of influenza viruses merge to create new pandemic strains? And what determines which species they may attack?

From our experiments we determined that the surface antigens of a virus are important for the virulence of a strain, but another part of the virus plays the major role in determining which species the virus can successfully multiply in. This became apparent when our research group produced a live vaccine of a lethal strain of avian influenza A virus, called fowl plague virus. We left its hemagglutinin gene intact but replaced other genes in the virus, rendering it harmless to chickens. This vaccine—a sheep in wolf's clothing—would alert the host's immune system while causing no harm. In chickens, the new virus was not pathogenic, but in another species, mice, it could now kill.

We determined that by replacing the gene coding for the nucleoprotein, we changed the host species that the fowl plague virus could attack. Nucleoproteins form the core of the virus, wrapping around the virus's genes. While surface antigens, such as hemagglutinin, are important for entering a host's cells, the nucleoprotein has to cooperate with almost all viral components in one way or another during multiplication, assembly, and maturation of infectious particles. Any of the viral genes can be exchanged without affecting host specificity except the nucleoprotein gene. Thus, when we replaced the gene segment responsible for the nucleoprotein in fowl plague virus with the corresponding gene from the human influenza virus, we were able to change the host specificity of the avian strain. The new virus could no longer multiply in chickens but could in dog cells and, presumably, in humans. Brian Murphy and his colleagues at the National Institutes of Health in Maryland have conducted the opposite experiment in their efforts to develop a live human influenza vaccine. They succeeded in rendering a human influenza virus harmless to monkeys by replacing the nucleoprotein gene with one from an avian strain.

Knowing that nucleoproteins play the key role in determining which species a virus can attack, we determined the amino acid sequences of nucleoproteins from many influenza A strains isolated from different species in various locations around the world. (Amino acids are the building blocks of proteins and are strung together in a specific sequence, like colored beads on a string.) By comparing these amino acid sequences from twenty-five viruses, Walter Fitch, of the University of California at Irvine, and I were able to construct an evolutionary tree that suggests the relationships between the vi-

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ruses. Two main branches were apparent: one consisting of all human strains; the other of the avian strains. Viruses from other mammals were found to be closely related to the avian viruses, except those from pigs. Viruses isolated from pigs either formed their own branch, swine influenza, or were scattered within the avian and human branches. This was consistent with the idea that pigs are the "mixing vessels" capable of becoming infected by viruses from human and avian reservoirs.

By the late 1960s, attention had already focused on the pig's role in creating new strains of influenza viruses. The concept that pigs are the mixing vessels for the creation of new human strains followed. Pigs probably become infected with avian influenza viruses after eating duck droppings and can catch the human virus from a farmer's sneeze or cough. If the pig is infected with both viruses at the same time, the genetic material can mix, creating a new strain that may find its way to the respiratory tract of a farmer and thus spread to the human population.

Changing age-old farming practices in China that allow mixing of avian influenza virus genes with those of human strains may prove difficult. Undoubtedly, new strains will continue to threaten world health. Although antibiotics to treat secondary pneumonia and rapidly developed vaccines to immunize against the newly emerging strain might lower the death toll, I see nothing preventing another disaster like the 1918–19 pandemic. Moreover, if we export the Blue Revolution to the rest of the world without precautions, such as keeping pigs in separate, enclosed farms, the probability of repeating such a disaster will be greatly increased.

The other observation we made by looking at the evolutionary tree was quite surprising. After human and avian influenza viruses split, human strains show considerable evolution, while the avian branch does not. We concluded that the nucleoproteins of the human strains are subjected to much stronger selection pressures than are their avian counterparts. This may reflect the adaptation to the new host of a protein that originated as part of an avian virus. Another possibility, not excluding the first, is that human strains always have to change to evade the host's immune response, and the variants that arise by mutation have slightly different nucleoproteins. These variants can infect human populations previously exposed to the parent strain, since the immune system is not equipped to recognize altered nucleoproteins. Duck viruses, on the other hand, are not under strong selection pressure, since they multiply in the intestines, where the immune defense does not need to combat them. In fact, antibodies are scarcely detectable in the blood of infected ducks. The virus may evolve slowly in other animals for a similar reason. Farm pigs, for instance, are usually slaughtered during their first year, so swine viruses will always encounter a new pig population, and the evolution of new strains to evade an immune response is not favored.

When we compare a fairly recent nucleoprotein from a human virus isolated in 1983 with that of a prototype duck virus, we see that they now differ in about forty amino acids. In the past, however, the two viruses resembled each other more closely. The human strain from 1933 reveals only twenty-five amino acids that do not match the sequence from the duck virus. Assuming that the mutation rate during the last fifty years reflects that of the previous years, we can extrapolate backward and see that the human virus and duck virus would have converged in about 1840. However, Webster and his colleagues have recently shown that the mutation rate immediately after introduction of a virus into a new species is rapid and then levels off with time. Thus, the real time of the introduction might have been closer to 1900.

But influenza is an ancient disease. Its symptoms were described 2,400 years ago by Hippocrates, and historical records on influenza exist from medieval times. Virulent strains of the virus similar to today's type A must have existed before the 1800s. Perhaps the mildly pathogenic influenza B and C viruses—which are found only in humans—also originated from an avian influenza A virus. Type B nucleoprotein shows a close genetic relationship to type A, while type C is more distantly related. Therefore, the influenza B virus might have been derived from an avian influenza A virus hundreds of years before the 1800s and stayed in the human population as an A virus until it finally evolved into a new type, the B virus. The influenza C virus might also fit this pattern, having evolved from an avian influenza A virus at an even earlier time.

In the winter of 1979–80, an influenza epizootic among camels in Mongolia resulted in great economic losses. Although ruminants normally are not regarded to be natural hosts for influenza A viruses, our Mongolian colleagues isolated the virus from several diseased animals in three consecutive years. Svetlana Yamnikova and her colleagues at the Ivanovsky Institute of Virology in Moscow found that the surface antigens of the viruses were identical to contemporary human strains. Our genetic analysis in Giessen revealed that the strains were recombinants between two human strains, one isolated in 1934 and the other in 1977. In Leningrad, such a virus was prepared and killed for use as a vaccine in the Mongolian population in the same years as the camel epizootic. The recombinant virus apparently somehow survived the process and was transmitted to a camel, which it successfully infected, and the epizootic followed. Thus, a recombinant vaccine safe for one species might be lethal to another.

The influenza virus has an interesting and chameleonlike evolutionary history. We should not contribute to the dangerous reassortment of the virus's genes, which occurs in nature all the time, by engaging in certain agricultural practices without proper precautions. Nor should we try to combat influenza by developing live recombinant influenza vaccines that might prove lethal to other species.

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Christoph Scholtissek is a virologist at the University of Giessen's Institute for Virology in Germany.

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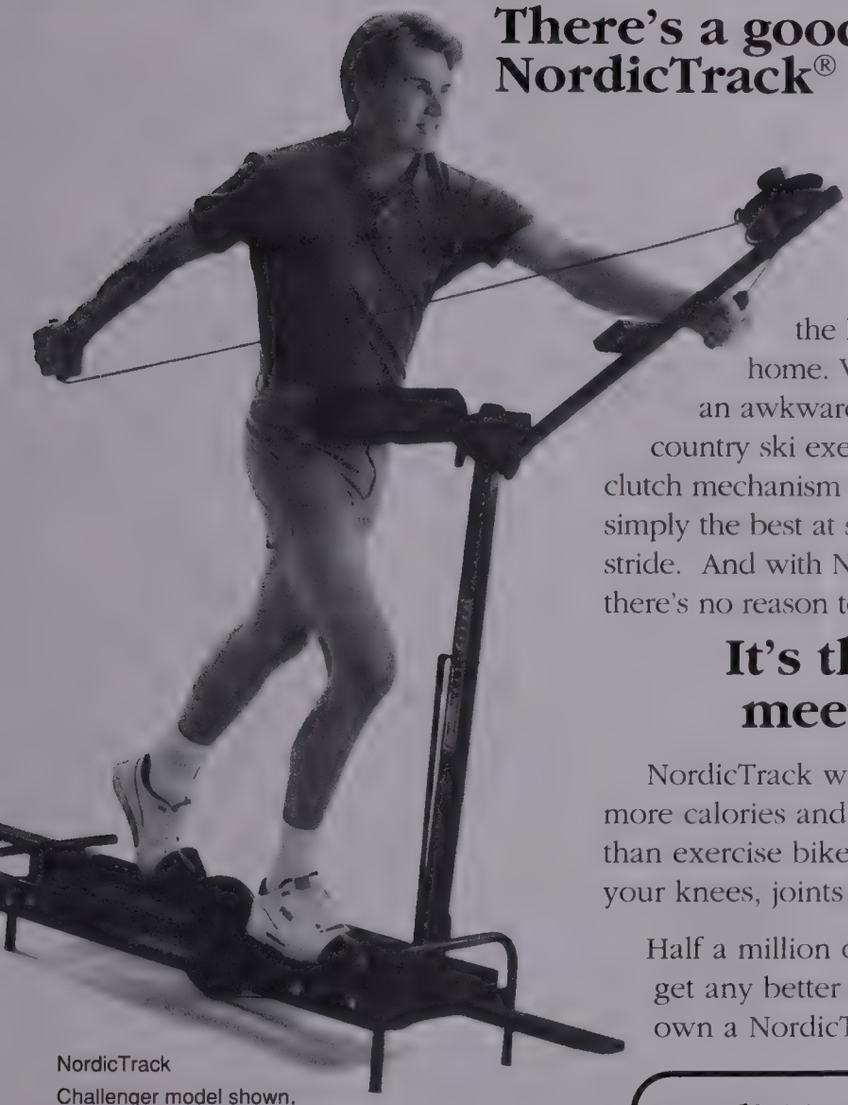

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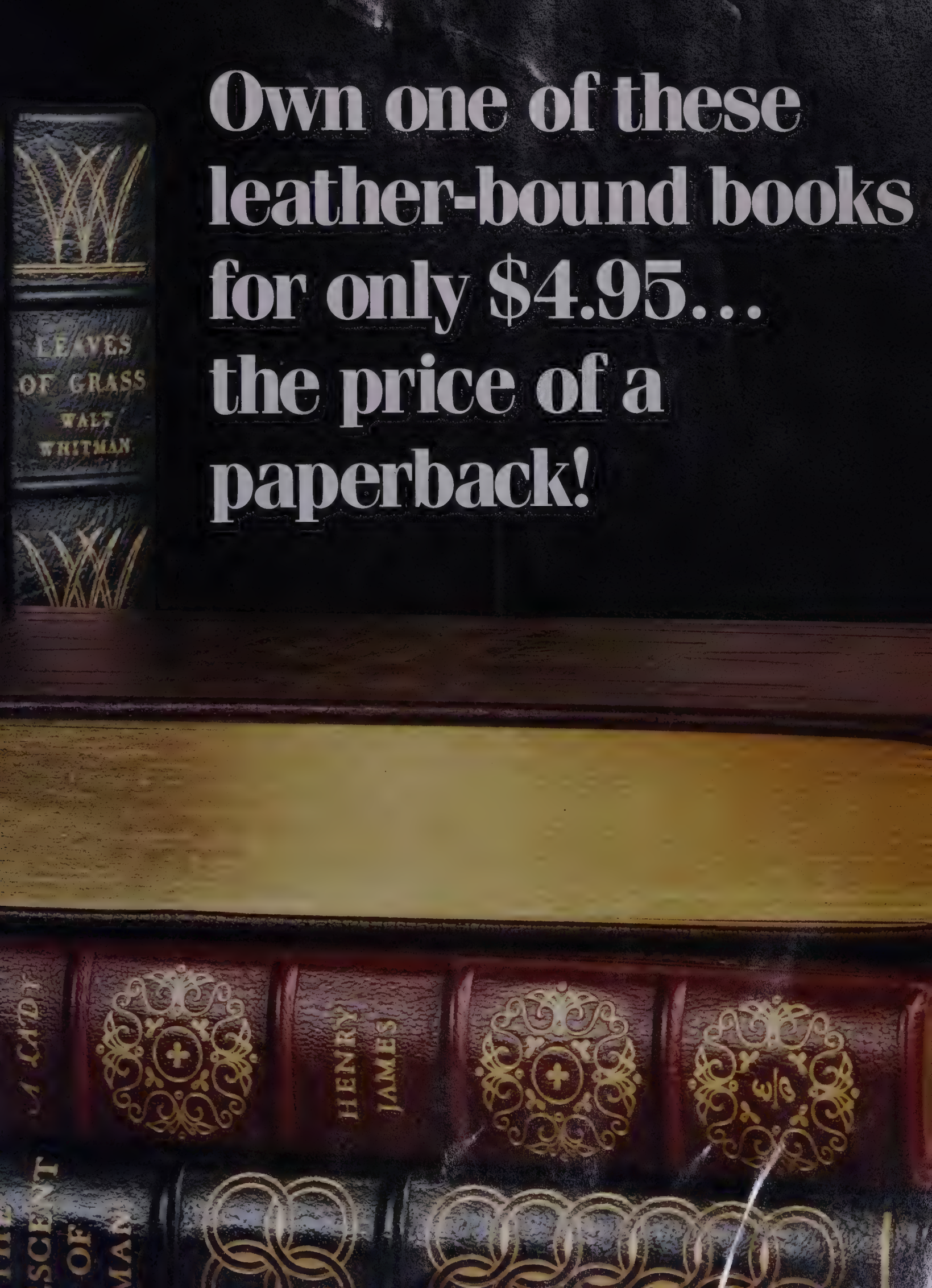

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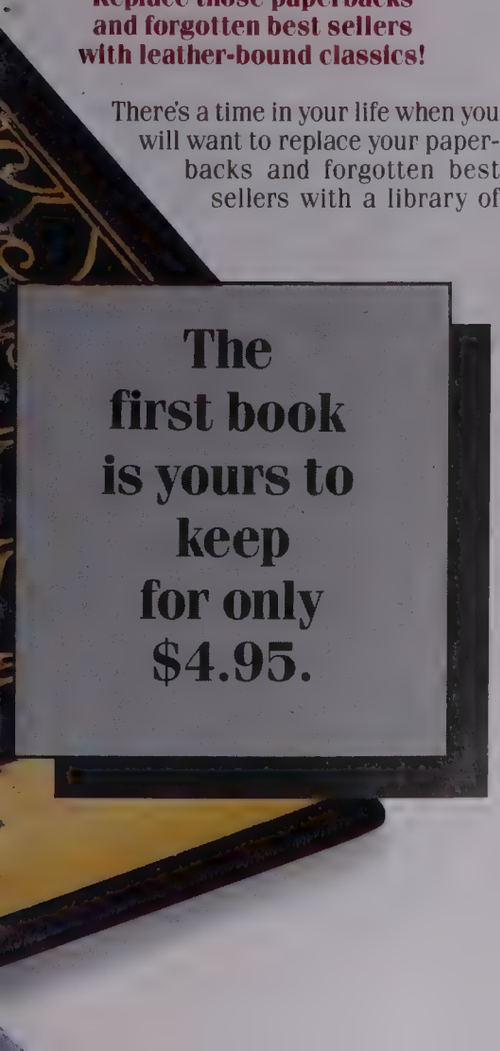

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The Reversal of *Hallucigenia*

Scientists have recently uncovered the impressive pedigree of a lowly, misunderstood creature

by Stephen Jay Gould

You can generate a lot of mischief just by strolling. When God asked Satan what he'd been doing, the foremost of the fallen angels responded: " . . . going to and fro in the earth and . . . walking up and down in it" (Job 1:7). But you can also do a lot of good. Aristotle preferred to teach while ambling along the covered walk, or *peripatos,* of his Lyceum in Athens. His followers were therefore called peripatetics. In Greek, a *patos* is a path, and *peri* means "about." The name for Aristotle's philosophical school therefore reflects the master's favorite activity.

The same etymology lies behind my all-time favorite technical name for an animal—the genus *Peripatus.* I just love the sound, especially when pronounced by my Scottish friends who really know how to roll their *r*'s. I can hardly ever bring myself to write about the animal without expressing delight in its name. The only reference in my book *Wonderful Life* speaks of the "genus with the lovely name *Peripatus.*"

Peripatus is an elongated invertebrate with many pairs of stout, fleshy legs—hence the chosen name for this obligate walker. The Reverend Lansdown Guilding—quite a name itself, especially given the old stereotype of English clergymen as amateur natural historians—discovered and designated *Peripatus* in 1826. He falsely placed his new creature into the mollusk phylum (with clams, snails, and squids) because he mistook the antennae of *Peripatus* for the tentacles of a slug. Since true mollusks don't have legs, Guilding named his new beast for a supposed peculiarity.

Peripatus is the most prominent member of a small group known as Onychophora. Modern onychophorans are terrestrial invertebrates of the Southern Hemisphere (with limited extension into a few regions of the Northern Hemisphere tropics)—hence little known, and never observed in natural settings by residents of northern temperate zones.

About eighty species of living onychophorans have been described. They live exclusively in moist habitats, usually amid wet leaves or rotting wood. Most species are one to three inches in length, although the size champion from Trinidad, appropriately named *Macroperipatus,* reaches half a foot. They resemble caterpillars in outward appearance (although not in close evolutionary relationship). They are elongated, soft bodied, and unsegmented (the ringlike "annulations" on antennae, legs, and sometimes on the trunk are superficial and do not indicate the presence of segments, or true divisions of the body). The onychophoran head bears three paired appendages: antennae, jaws, and just adjacent to the jaws, the so-called slime papillae. Onychophorans are carnivores and can shoot a sticky substance from these papillae, thus ensnaring their prey or their enemies. Behind the head, and all along the body, onychophorans carry fourteen to forty-three pairs (depending on the species) of simple walking legs, called lobopods. The legs terminate in a claw with several spines—the source of their name, for Onychophora means "talon bearer."

The Onychophora present the primary case for a classical dilemma in taxonomy: how do we classify small groups of odd anatomy. (Oddness, remember, is largely a function of rarity. If the world contained a million species of onychophorans and only fifty of beetles, we would consider the insects as bizarre.) The chief fault and foible of classical taxonomy lies in its passion for clean order—an imposition bound to distort a messy world of continuity and complexity. A small group of distinctive anatomy sticks out like the proverbial sore thumb, and taxonomists yearn to heal the conceptual challenge by enforcing an alliance with something more familiar. Two related traditions have generally been followed in this attempt, both misleading and restrictive: the shoehorn ("cram 'em in") and the straightening rod ("push 'em between").

The shoehorn works by cramming odd groups into large and well-established categories, usually by forced and fanciful comparison of one or two features with characteristic forms of the larger group. For example, the Onychophora have sometimes been allied with the Uniramia, the dominant arthropod group that includes insects and myriapods (millipedes and centipedes), because both have single-branched legs (never mind that arthropod legs are truly segmented and that onychophoran lobopods are constructed on an entirely different pattern).

The straightening rod tries to push a jutting thumb of oddness back into a linear array by designating the small and peculiar group as intermediary between two large and conventional categories. The Onychophora owe whatever small recognition they possess to this strategy—for they have most commonly been interpreted as living relicts of the evolutionary transition between two great phyla: the Annelida (segmented worms, including leeches and the common garden earthworm) and the Arthropoda (about 80 percent of animal species, including insects, spiders, and crustaceans). In this argument, *Peripatus* is a superworm for its legs and a diddly fly for building these legs without true segments.

A third possibility obviously exists and

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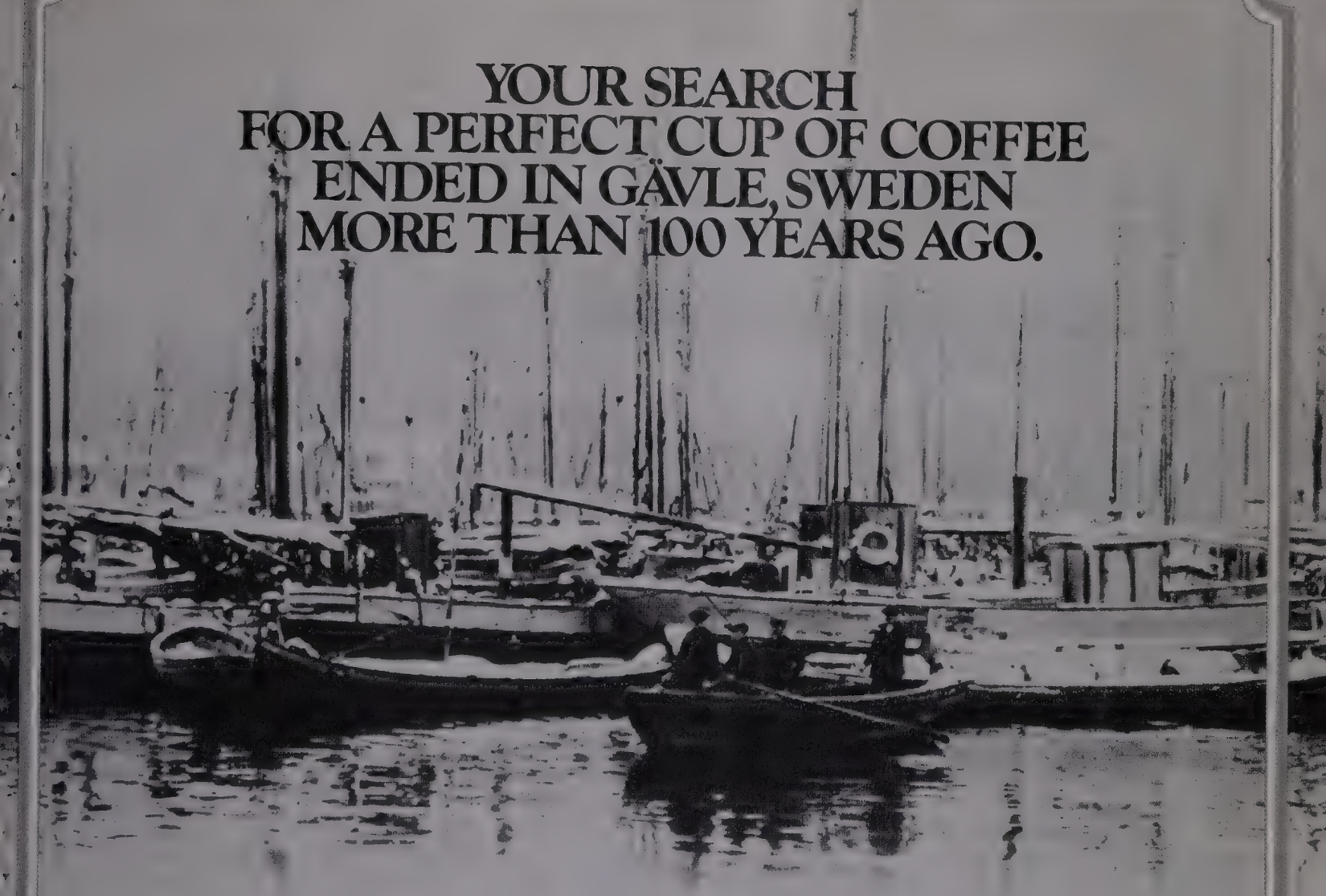

Victor Th. Engwall

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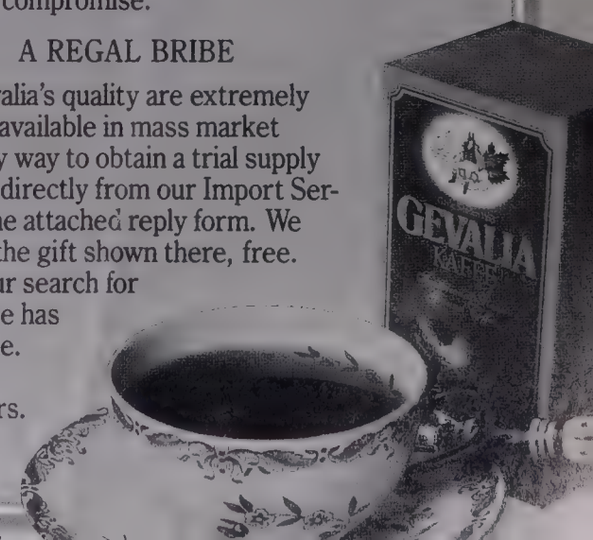

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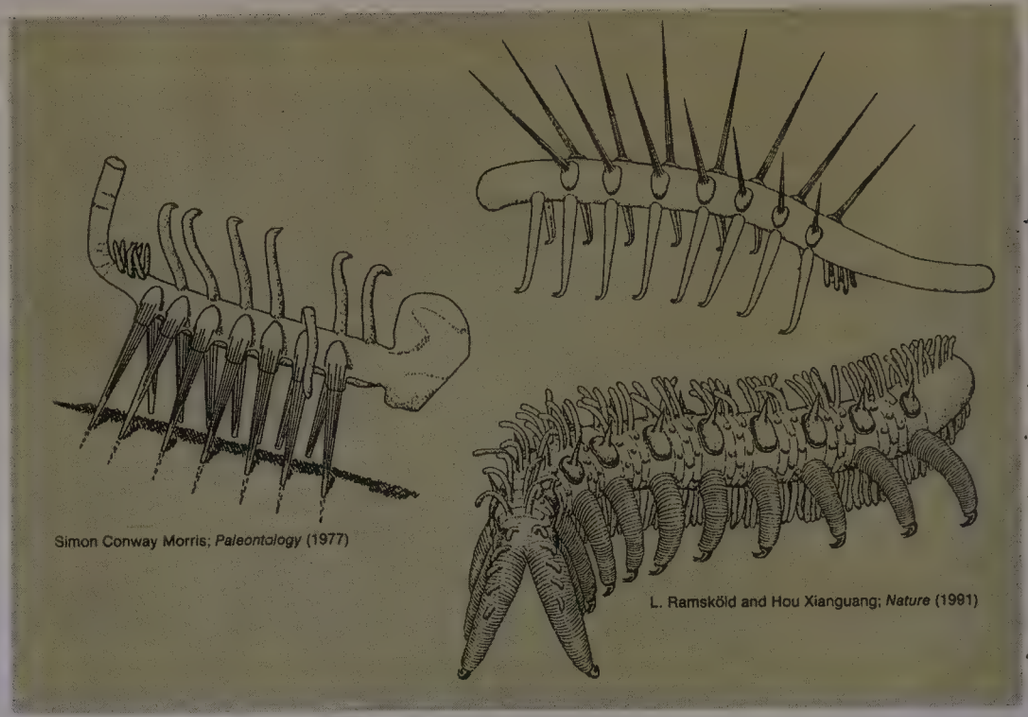

Left: Conway Morris's original reconstruction of Hallucigenia. *Right, top and bottom: Ramsköld and Hou's inversion of* Hallucigenia *as an onychophoran and their reconstruction of the new Chengjiang onychophoran with side plates and spines.*

clearly bears interesting implications. This third way has been supported, often by well-respected taxonomists, but our general preference for shoehorns and straightening rods has given it short shrift. The Onychophora, under this view, might represent a separate group, endowed with sufficient anatomical uniqueness to constitute its own major division of the animal kingdom, despite the low diversity of living representatives. After all, the criterion for separate status should be degree of genealogical distinctness, not current success as measured by number of species. A lineage may need a certain minimal membership just to have enough raw material available so that evolution can craft sufficient difference for high taxonomic rank. But current diversity is no measure of available raw material through geological history. Evolution is ebb and flow, waxing and waning; once great groups can be reduced to a fraction of their past glory. A great man once told us that the last shall be first, but just by the geometry of evolution, and not by moral law, the first can also become last. Perhaps the Onychophora were once a much more diverse group, standing wide and tall in their distinctness, while *Peripatus* and its allies now form a pitifully reduced remnant.

(By speaking of potential distinctness, I am not making any untenable—indeed it would be nonsensical—claim for total separation without any relationship to other phyla. Very few taxonomists doubt that onychophorans, along with other potentially distinct groups known as tardigrades and pentastomes, have their evolutionary linkages close to annelids and arthropods. But this third view places onychophorans as a separate limb of life's tree—branching off near the limbs of annelids and arthropods and eventually joining them to form a major trunk—whereas the shoehorn would stuff onychophorans into the Arthropoda, and the straightening rod would change life's geometry from a tree to a line and place onychophorans between primitive worms and more advanced insects.)

We can only test this third possibility by searching for onychophorans in the fossil record—a daunting task because they have no preservable hard parts and therefore do not usually fossilize. I write this essay because several striking new discoveries and interpretations, all made in the past year or two, now point to a markedly greater diversity for onychophorans right at the beginning of modern multicellular life, following the Cambrian explosion some 550 million years ago. These discoveries arise from two fortunate and quite different circumstances: first, onychophorans have been found in the rare soft-bodied faunas occasionally preserved by happy geological accidents in the fossil record; second, some ancient onychophorans possessed hard parts and can therefore appear in ordinary fossil deposits.

I fully realize that this expansion in onychophoran diversity at the beginning of multicellular animal life can scarcely rank as the hottest news item of the year. Most readers of this column, after all, have probably never heard the word *onychophoran* and, lamentably, have no acquaintance with poor, lovely *Peripatus*. So why get excited about old onychophorans if you never knew that modern ones existed in the first place? Do hear me out

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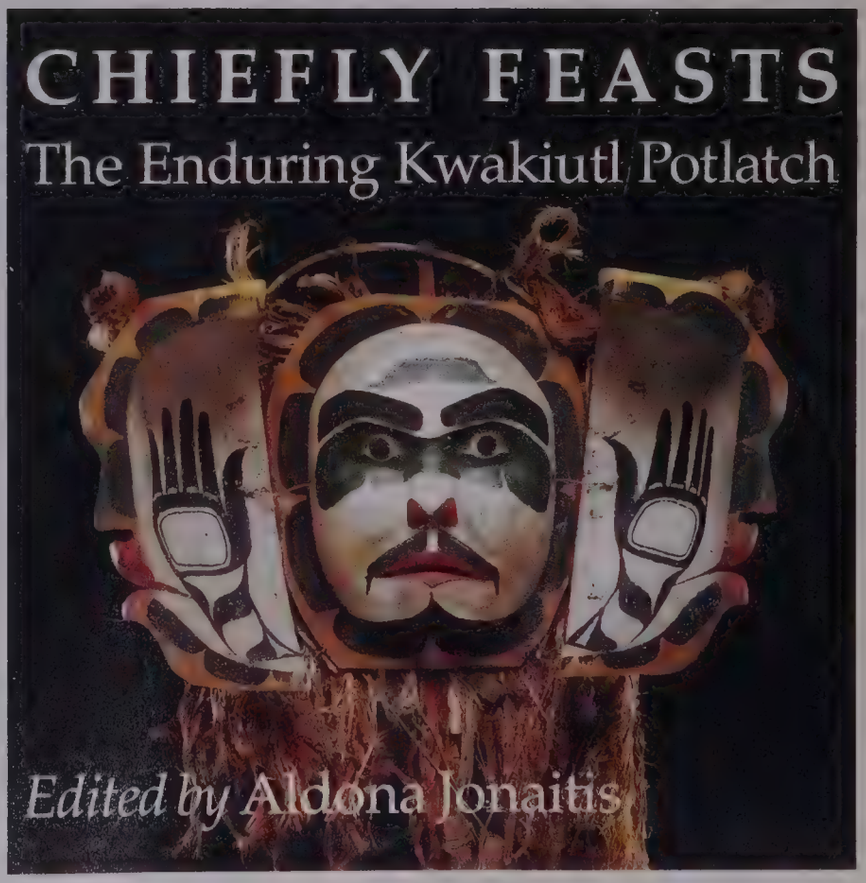

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if you harbor these doubts. Much more than *Peripatus* lies at stake, for validation of the third position—that onychophorans represent a separate branch of life's tree—has broad and interesting implications for our entire concept of evolution and organic order. I also think that you will marvel at the details of these early onychophorans for their own sake—and their weirdness.

We have actually known a bit about ancient onychophorans for most of this century, thanks once again to that greatest of treasure troves for soft-bodied fossils, the Burgess Shale. In 1911, two years after discovering the Burgess Shale, C. D. Walcott gave the unpronounceable name *Aysheaia* (we generally call it a-shy-a in the trade) to an animal that he described as an annelid worm. Many taxonomists, just viewing Walcott's illustrations, immediately saw that the creature looked much more like an onychophoran. In 1931, G. Evelyn Hutchinson, who became the world's greatest ecologist and was, perhaps, the finest person I have ever had the privilege of knowing (he died just a few months ago in his early nineties), published a definitive account on the onychophoran affinities of *Aysheaia.* Hutchinson had studied *Peripatus* in South Africa and he knew onychophoran anatomy intimately. As an ecologist, he was powerfully intrigued by the issue of how an ordinary marine invertebrate like *Aysheaia* could evolve into a terrestrial creature like *Peripatus* with such minimal change in outward anatomy. (*Aysheaia* had fewer pairs of legs and fewer claws per leg than do modern onychophorans. It also bore a terminal mouth at the body's end, while living onychophorans have a ventral mouth on the underside. In addition, *Aysheaia* had no slime papillae and could not use such a device to shoot sticky stuff through ocean waters in any case. But, all told, the differences are astonishingly slight for more than 500 million years of time and a maximal ecological shift from ocean to land.)

One other ancient onychophoran was recognized before last year—a European form named *Xenusion,* found during the 1920s. But *Aysheaia* and *Xenusion* did not shake the shoehorn or the straightening rod. Only two fossils, both so similar to modern forms, do not make an impressive show of diversity. Onychophorans remained a tiny and uniform group, ripe for stuffing in or between larger phyla and not meriting a status of its own.

In a recent column (October 1990) I described the beginning of the onychophoran coming of age (I was going to say "renaissance," but a renaissance is a rebirth, and onychophorans never had an earlier period of flowering in our consciousness). In that essay, and in another context, I described the discovery in China of the animal that bore the small, circular, meshwork plates known for many years from lowermost Cambrian rocks as *Microdictyon.* This fossil comes from the remarkable Chengjiang fauna of south-central China, a Burgess Shale equivalent (although slightly older), with beautiful soft-bodied preservation of many animals already known from the more famous Canadian site (and several novelties as well, including the *Microdictyon* animal). The plates called *Microdictyon* are attached in pairs to the side of the animal just above the junction of paired lobopods with the trunk of the body. The animal itself looks like an onychophoran. If this interpretation holds, then some ancient onychophorans had hard parts. The Chengjiang fauna also contains a second probable onychophoran with plates, named *Luolishania.*

Thus, the early fossil record of onychophorans had begun to expand in numbers and anatomical variety, including both fully soft-bodied forms like *Aysheaia* and creatures with small pairs of plates like *Microdictyon* and *Luolishania.* But the big boost, the event that might finally push onychophorans over the border of distinct respectability, finally occurred on May 16, 1991, when the Swedish paleontologist L. Ramsköld and his Chinese colleague Hou Xianguang published an article in the British journal *Nature* (science, at its best, is truly international): "New Early Cambrian Animal and Onychophoran Affinities of Enigmatic Metazoans" (vol. 351, pp. 225–28).

Ramsköld and Hou dropped a bombshell that makes elegant sense of a major paleontological puzzle of recent years. In 1977, Simon Conway Morris described the weirdest of all Burgess Shale organisms with the oddest of all monikers: *Hallucigenia,* named, as Conway Morris wrote, for "the bizarre and dream-like appearance of the animal." He described *Hallucigenia* as a tubular body supported by seven pairs of long, pointed spines—not jointed arthropod appendages or fleshy lobopods, but rigid spikes. In Conway Morris's reconstruction, a single row of seven fleshy tubes, each ending in a pair of little pincers, runs along the back, with a tuft of six smaller tubes, perhaps in three pairs, behind the larger seven. The head, not well preserved on any specimen, was depicted as a bulbous extension and the tail as a straight, upward-curving tube.

Hallucigenia was bizarre enough in appearance, but even more puzzlement attended the issue of how such a creature could function. In particular, how could a tiny animal, no more than an inch in length, be stable on seven pairs of rigid spikes for "legs"? And if stable, how could it possibly move? Some of our best functional morphologists, including Mike Labarbera of the University of Chicago, struggled with this issue and could not resolve it.

The unlikely morphology, and the even

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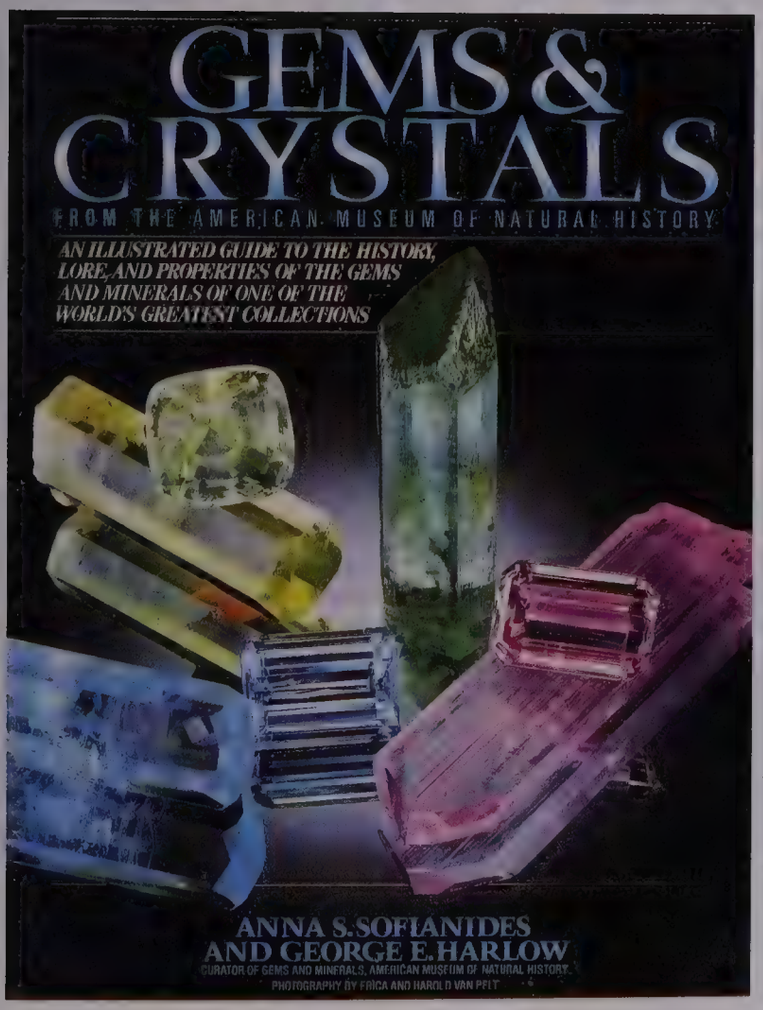
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more troublesome question of function, led many paleontologists to dispute Conway Morris's reconstruction (and Conway Morris himself also began to doubt his original conclusions). In my book *Wonderful Life,* I presented Conway Morris's original version and then opted for a different interpretation proposed by several colleagues before me—that *Hallucigenia* is a part broken off from a larger (and still unknown) animal. I wrote:

> *Hallucigenia* is so peculiar, so hard to imagine as an efficiently working beast that we must entertain the possibility of a very different solution. Perhaps *Hallucigenia* is not a complete animal, but a complex appendage of a larger creature, still undiscovered. The "head" end of *Hallucigenia* is no more than an incoherent blob in all known fossils. Perhaps it is no head at all, but a point of fracture, where an appendage (called *Hallucigenia*) broke off from a larger main body.

I received several dozen much appreciated letters from readers of my book, suggesting different reconstructions for some of the oddball creatures of the Burgess Shale. *Hallucigenia* received the lion's share of attention—and one suggestion cropped up again and again, in at least twenty separate letters. These correspondents, nearly all amateurs in natural history, pointed out that *Hallucigenia* would make much more sense turned upside down—for the spines, which never worked in locomotion, could then function far more reasonably for protection!

I responded to these letters with, for me, the decisive rejoinder that a single row of tentacles (Conway Morris's version of the upper surface) would work even more poorly than paired spines as devices of locomotion. How could an animal balance, not to mention hop around, on a single row of tentacles? Yet I couldn't deny that everything else made more sense upside down.

It doesn't happen often, but if Ramsköld and Hou are correct—and I think they are—then the gut feeling of amateurs has triumphed over the weight of professional opinion. For Ramsköld and Hou have, unbeknownst to them of course, followed the advice of my correspondents. They have turned *Hallucigenia* upside down, but with an added twist (intellectual, not geometric) as well—they have inverted it into an onychophoran!

Ramsköld and Hou present two major arguments for their inversion of *Hallucigenia.* First, they must tackle the issue that hung me up: how can a single row of tentacles function as legs? They acknowledge the problem, of course, but suggest that Conway Morris was wrong, and that two rows of paired tentacles are actually present along the surface that he called dorsal, or topmost. If Ramsköld and Hou are correct, then the major objection to reversing *Hallucigenia* disappears—for two rows of flexible tentacles look like the ordinary legs of a bilaterally symmetrical creature. Moreover, when you turn *Hallucigenia* upside down on the assumption that two rows of tentacles adorn the topside of Conway Morris's version, then the inverted beast immediately says "onychophoran" to any expert, for the little paired pincers at the end of each tentacle become dead ringers for onychophoran claws. Ramsköld and Hou have not yet developed enough evidence to prove the double row of tentacles conclusively, but our museum at Harvard contains the sample best suited for resolving this issue—a slab of rock with more than a dozen *Hallucigenia* specimens. I have lent this slab to Ramsköld and Hou, and I suspect that an answer will soon be forthcoming.

Second, they must explain how an onychophoran could possess the several pairs of long, pointed, upward-protruding spines that an inversion of *Hallucigenia* places along the top edge of the animal—for some fossil onychophorans bear plates (*Microdictyon* and *Luolishania* as previously discussed), but none yet described carry spines. Here, Ramsköld and Hou present compelling evidence in a form much favored by natural historians—a sequence or continuum linking a strange and unexpected form to something familiar through a series of intermediates.

Start the series with *Microdictyon.* This animal, probably an onychophoran, carried pairs of flat plates along the side of its body just above the insertion of lobopods. Go next to a new and as yet unnamed "armored lobopod," again from the prolific Chengjiang fauna. This clear onychophoran also bore paired plates in the same position as in *Microdictyon.* But each plate now carries a small spine—nothing like the elongation in *Hallucigenia,* but evidence that onychophoran plates can support spines. For a third step, go to isolated plates collected in lower Cambrian rocks of North Greenland by J. S. Peel and illustrated by Swedish paleontologist Stefan Bengtson in a commentary in *Nature* written to accompany Ramsköld and Hou's paper. These Greenland plates have the same meshwork structure as those of *Microdictyon*—and onychophoran affinity seems a reasonable conjecture (although in this case, we have only found preserved plates, not the entire body). But the Greenland plates carry spines verging on the length of *Hallucigenia* spikes. It is now only a small step to a fourth term in the series—to an onychophoran bearing plates with highly elongated spines: in other words, to *Hallucigenia* turned upside down!

We are witnessing a veritable explosion of Cambrian onychophorans—*Aysheaia* and *Xenusion* with their soft bodies, *Microdictyon* and *Luolishania* with plates, the unnamed Chengjiang creature

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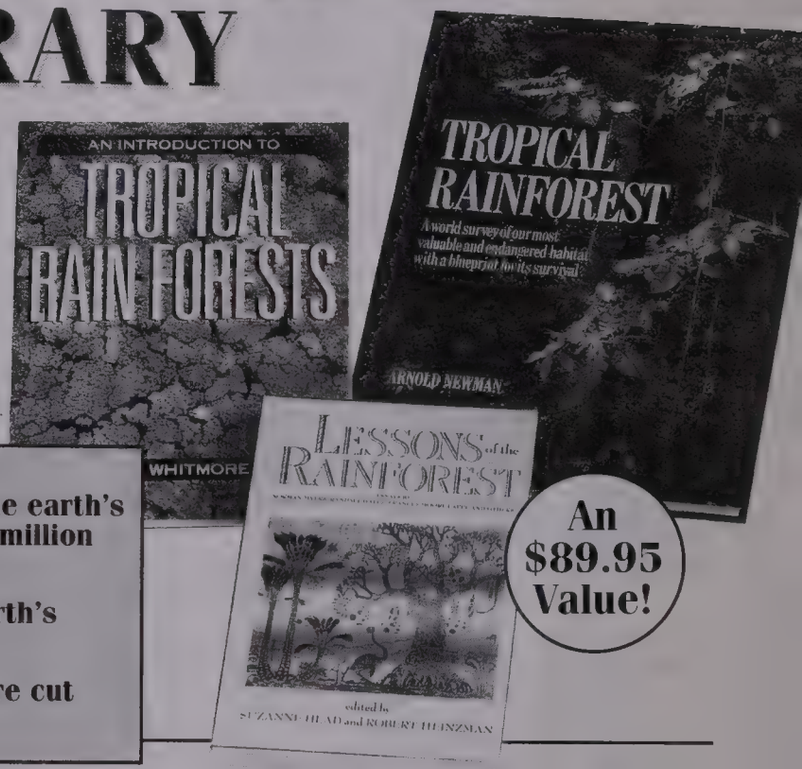
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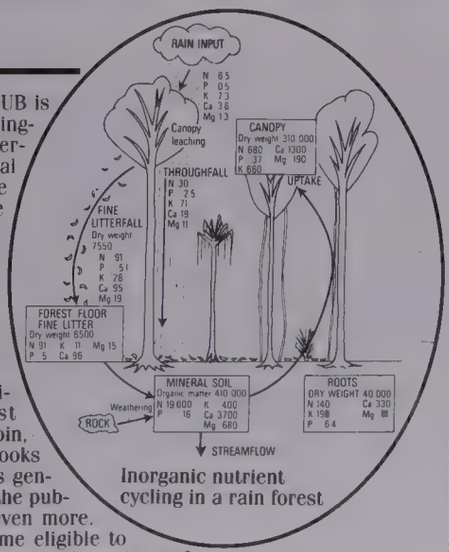

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with plates and short spines, the Greenland form with longer spines, and finally, inverted *Hallucigenia* with greatly elongated spines.

The reversal of *Hallucigenia* has capped and sealed the tale. The larger conclusion seems inescapable: in the great period of maximal anatomical variety and experimentation that followed right after the Cambrian explosion first populated the earth with multicellular animals of modern design, the Onychophora represented a substantial and independent group of diverse and successful marine organisms. The modern terrestrial species are a tiny and peripheral remnant, a bare clinging to life for a lineage that once ranked among the major players. The shoehorn and straightening rod have served us poorly as strategies of interpretation. Groups with few species may be highly distinct in genealogy.

Onychophorans, moreover, are not the only small cluster of straggling survivors within groups that were once major branches of life's tree. The distinct phylum of priapulid worms, for example, contains fewer than 20 species worldwide, compared with some 8,000 for marine polychaete worms, members of the dominant phylum Annelida. Yet, in the Cambrian period at the beginning of multicellular history, priapulids and polychaetes were equally common and similarly endowed (or so it seemed) with prospects for long-term success. Moreover, just as onychophorans have held on by surviving in the peripheral habitat of terrestrial life (for a formerly marine group), modern priapulids all live in harsh and marginal environments—mostly in cold or deep waters and often with low levels of oxygen.

In recognizing the Onychophora as a distinct group with an ancient legacy of much greater breadth, we may regret the loss of tidiness provided by the shoehorn and straightening rod, but we should rejoice in the interesting conceptual gains. For by our latest reckoning of life's early history, "uncomfortable" groups like the Onychophora should exist today. We once thought that the history of life moved upward and outward from simple beginnings in a few primitive, ancestral lines to ever more and ever better—the conventional notion that I have called the cone of increasing diversity. On this model, an ancient and distinctive genealogical status for several small groups (like the Onychophora) makes no sense—for life's early history, at the point of the cone, shouldn't have featured many distinct anatomies at all. The large living groups of mollusks, arthropods, annelids, vertebrates, and so on—all of which have fossil records extending back to this early time—provide quite enough material for legacies from these early times of limited simplicity. But the reinterpretation of the Burgess Shale, and our burgeoning interest in the early history of multicellular life in general, have indicated that the cone model is not only wrong but also backward. Life may have reached a maximal spread of anatomical experimentation in these early days—and later history may be epitomized as a diminution of these initial possibilities by decimation, rather than a continual expansion.

In this reversed model of a grass field, with most blades clipped off and just a few proliferating wildly thereafter, we should expect to find a fair number of blades that survived the mower but never flowered extensively again—whereas, in the cone model, the forest of blades never existed, and the early history of life provides insufficient raw material for many distinct modern groups such as the Onychophora.

However much I may regret the loss of a wonderful weirdo in the reversal of *Hallucigenia,* and in its consequent change in status from oddball to onychophoran, I am more than compensated by fascinating insight into the history of the ancestors of my favorite name bearer, *Peripatus.* I revel in the knowledge that these marginal and neglected animals belong to a once-mighty group that included armored members with plates and long spines. And I rejoice in the further knowledge thus provided about the strange and potent times of life's early multicellular history. (My regret, in any case, could not possibly be more irrelevant to nature's constitution, either now or 500 million years ago. *Hallucigenia* was what it was: my hopes, and those of any scientist, are only worth considering as potential biases that can block our understanding of nature's factuality.)

Peripatus may walk prouder in the pleasures of pedigree. We humans, as intellectual descendants of Aristotle, the original peripatetic, might consider a favorite motto from "the master of them that know"—well begun is half done (from the *Politics,* book 5, chapter 4). Apply it first to the onychophorans themselves—for in a tough world dominated by contingent good fortune in surviving extinction, a good beginning of high diversity affords maximal prospect for some legacy long down the hard road. But apply it also to us, the paleontologists who strive to understand this complex history of life. By turning *Hallucigenia* upside down, we have probably taken a large step toward getting the history of life right side up.

"Here it is . . . the map—the Unpainted Desert."

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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Out Cold

The winter life of painted turtles

by Janet M. Storey and Kenneth B. Storey

One frosty morning last November, our daughters ran yelling into the house carrying a quarter-inch-thick sheet of ice with one of their pet painted turtles trapped solidly in its center. The surface of the backyard wading pool, the turtle's summer home, had frozen overnight, and the girls feared that the turtle was dead. As soon as a little tap water had melted the ice, however, the turtle stretched its legs and poked its head out of the shell. We knew that the shallow pool would freeze to the bottom in a few more days, so our pet was moved and spent the rest of the winter in the relative comfort of one of our laboratory cold rooms at Carleton University, where we are studying how animals deal with cold. Some of the most intriguing strategies for winter survival belong to painted turtles.

Widespread over most of the United States and southern Canada, the painted turtle ranges farther north than any other land or freshwater turtle in North America. The four subspecies (eastern, midland, western, and southern) are identified by distinctly different shell patterns.

After breaking open its egg, a young painted turtle, above, emerges. It will remain in the nest throughout the winter. Left: A common sight on hot summer days, painted turtles bask on rocks or partly submerged logs.

A. B. Sheldon

Painted turtles begin life as soft-shelled eggs laid in a two- to three-inch-deep nest scooped out by the female in sandy soil. Nest sites are usually located on bare, sloping banks with good southern exposure to insure high incubation temperatures for the eggs.

In our study area in south-central Canada, midland painted turtles nest on warm nights from mid-June onward. An average clutch comprises seven to nine eggs, with some females laying two clutches spaced some days apart. Once the nest is covered, the female leaves her brood to incubate. The young turtles hatch ten or eleven weeks later, but surprisingly, they don't leave the nest at this time. Instead, they remain hidden underground all winter. There they are safe from predators until spring arrives. But how do they survive when the temperature drops well below the freezing point of their body fluids?

In 1987, we set out to discover the winter survival strategy of hatchling painted turtles. First, we needed to know the midwinter temperatures within the nest cavities. For this we turned to our colleague Ron Brooks, of the University of Guelph, an expert on the reproductive biology of turtles, who had worked for years with a population of midland painted turtles in Algonquin Provincial Park, north of Toronto. Because this population lives so close to the northern limit of the species' range, we reasoned that this group would have maximized their defenses against the cold.

In the summer of 1987, Ron and his students marked several nests in their study area and carefully placed thermistors in the egg cavities of two nests to record winter temperatures. We found that during the winter of 1987–88, the young turtles did indeed experience long periods of exposure to freezing temperatures. Despite the insulation of the ground and a thick layer of snow, temperatures in the nest cavities ranged from 18° F to 28° F throughout January and February. When we dug out the nests in April, however, out popped thirteen live turtles. We found a few unhatched eggs containing dead embryos, but all the hatchlings had survived the winter.

We took these young turtles back to our laboratory to determine how they endured such low temperatures. We wanted to know whether the turtles' body fluids could remain in a liquid state even when their body temperature dropped far below its normal freezing point, as is the case with many polar insects and spiders, or whether these turtles had mastered the ability to endure freezing of their body fluids without damage to cells and organs.

To determine the strategy used by the hatchlings, we taped thermistors to their lower shells and then cooled the animals slowly in a temperature-controlled incubator. We watched as they cooled below the normal freezing point of turtle blood, 31° F. Indeed, their body fluids remained liquid until the temperature dropped to 26.5° F. Then, the hatchlings suddenly froze. We next lowered the temperature a little further to 25° F and left the turtles frozen for twenty-four hours. When we thawed them, they recovered fully. From newer studies, we now know that the turtles can survive being frozen at temperatures this low for at least eleven days. Recent tests with hatchlings of the western subspecies from Turtle Mountain Provincial Park in Manitoba have come up with similar results.

Our combination of laboratory and field studies was the first conclusive demonstration that a reptile could survive freezing, a capacity that is clearly lacking in humans and, indeed, all warmblooded animals. Since then, we and other researchers have found that box turtles and pond sliders, garter snakes and some lizards can endure freezing, although the ability varies widely between species. Some years ago we showed similar adaptations in land-hibernating frogs (wood frogs, gray tree frogs, spring peepers, and chorus frogs). Among reptiles, however, painted turtles seem to have the most well-developed tolerance to freezing.

When hatchling turtles freeze, ice first forms on the outer skin. Over the next several hours, ice grows inward toward the body core, gradually cutting off blood circulation to the periphery, until only the central heart–brain corridor is serviced. Ultimately, even this circulation is lost,

and eventually there is no muscle movement, no breathing, heartbeat, or blood flow, and only minimal brain activity. Soon after the animals thaw, however, the vital signs resume one after another.

Turtles, as well as other animals that endure freezing, can survive only if ice formation is restricted to extracellular body fluids (such as blood plasma, abdominal fluid, urine). In fact, we found that even in painted turtles, only 53 percent of their total body water froze at 25° F. The water within cells must remain liquid, however, because intracellular ice crystals will irreparably damage the internal organization and structure of cells. Therefore, freeze-tolerant animals have developed specific biochemical adaptations that control ice formation and protect their cells.

One of these adaptations is the synthesis of special ice-nucleating proteins. Probably in response to dropping temperatures, these proteins are made in the liver and then taken up by the blood plasma to be distributed to all extracellular fluids. Whenever the body temperature of the animal cools to just below the freezing point of plasma, these ice-nucleating proteins actually stimulate, or seed, ice formation but help keep crystals small, so that delicate tissues are not damaged. Our latest research, in collaboration with Jack Duman of Notre Dame University, has shown that hatchling painted turtles possess such proteins, whereas the adult turtles do not.

In freeze-tolerant animals, the beginning of ice formation outside the cells triggers a protective reaction within the cells: formation of high concentrations of sugar compounds, called cryoprotectants. These have two functions. They protect cell membranes and proteins from damage and, much like the antifreeze that we add to a car radiator, prevent the water inside cells from freezing. In painted turtles, we have found that such cryoprotection is probably due to the carbohydrates glucose, glycerol, and lactate, as well as the amino acid taurine.

After their first winter, painted turtles lose their ability to endure freezing. For the rest of their lives, they spend winters hibernating underwater on pond, lake, and river bottoms—sometimes resting on the surface of the sediment; at other times, buried in mud. The choice of location may depend on temperature, because painted turtles seem to prefer hibernation sites with temperatures between about 37° F and 43° F, where they are considerably warmer than their progeny on land. The turtles prefer to hibernate in shallow waters but move to deeper areas or dig into the warmer sediment when the water temperature falls closer to 32° F as the winter months pass.

But why does a turtle remain in shallow water when deeper water is less likely to freeze? The answer may be that the risk of being killed when the water freezes down into the sediment is outweighed by the turtle's need to position itself where it can detect the springtime warming of the water that is its cue for emergence from hibernation.

How do painted turtles survive the whole winter underwater without breathing? When a turtle is submerged, the oxygen content of its blood falls rapidly to near zero, a level that would be fatal to humans in three or four minutes but which can be endured by a hibernating turtle for three to four months. Indeed, painted turtles (as well as their close cousins the pond sliders) have by far the greatest tolerance for total deprivation of oxygen of any vertebrate animal, being able to live in completely deoxygenated water at 37° F for more than 150 days.

Some amphibians and reptiles bypass lung breathing, taking up oxygen and releasing carbon dioxide by direct gas exchange with the water through the skin or across the membrane lining the throat (a process called buccopharyngeal respiration). At temperatures near 32° F, when the dissolved oxygen content of water is

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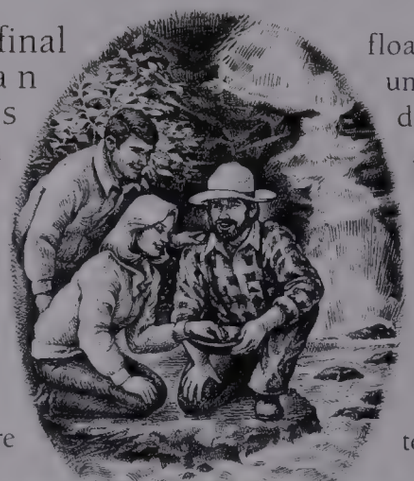

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high and the metabolic rate of animals is low, this mode of respiration can be significant. Indeed, frogs that hibernate underwater maintain nearly normal levels of tissue oxygen by gas exchange across the skin. Some extrapulmonary respiration may also occur in hibernating painted turtles. Studies have shown that survival time is greater and metabolic stress lower when turtles are submerged in oxygenated rather than deoxygenated water. However, painted turtles also need to cope with total oxygen deprivation when they burrow into bottom mud or when the oxygen content of the water falls to zero, as often occurs in the latter part of the winter in ice-locked waters.

Without oxygen-based respiration, human cells cannot generate energy rapidly enough to match the energy demands of the host of biochemical reactions taking place in our cells. After only a few minutes without oxygen, the human brain has exhausted its energy supply, and its electrical activity degenerates irreparably.

In the painted turtle, however, critical adaptations of its metabolism allow long-term life without oxygen. The choice of fuel for winter metabolism is very important. In summer and in autumn, a turtle stores large reserves of carbohydrate fuel—glycogen—in all its organs. Glycogen (unlike lipids or proteins) can be broken down to generate energy by a pathway that does not require oxygen. This pathway (called glycolysis) yields lactic acid as its product, and in high levels, this acid can poison animal cells. But the painted turtle has developed an effective means of neutralizing the acid buildup. This is done by buffering the acid with calcium and magnesium released from the turtle's shell and bone.

Important as these factors are, however, it is another adaptation, "metabolic arrest," that is most critical to sustained survival without oxygen. Metabolic arrest greatly reduces the cells' rate of energy use and thus lengthens the time that an animal can live on a fixed reserve of body fuel. This "dormancy" phenomenon is also evident in many hibernating mammals and estivating desert creatures. In painted turtles, metabolic arrest is triggered by oxygen deprivation.

The metabolic rate of a turtle submerged in 37° F water drops rapidly over a few hours until it is only about 10 percent of the rate for the same animal in equally cold air. This drop in metabolic rate means a tenfold extension of the time that stored body fuels can support life. From our recent studies of turtle metabolism, we know that the actions of many cellular proteins (such as enzymes or the "transporter" proteins in membranes) can be slowed down by chemically modifying their structures. Hormonal signals, perhaps responding to carbon dioxide buildup in the plasma, may function to coordinate this process in all organs.

The mechanisms involved in both freeze tolerance and metabolic arrest have important potential applications in biomedicine. As an animal that has evolved natural freeze tolerance and the ability to go into metabolic arrest, the painted turtle can show us some of the cellular and molecular adjustments needed for organs to endure freezing or sustain a long dormancy. At present no mammalian organ has ever been restored to a viable state after freezing, and organs removed for transplant can be held on ice for only a few hours before their metabolism degenerates irreversibly. The knowledge gained from studies of painted turtle organs could, therefore, have important applications for the advancement of medical organ transplant technology. Amazing lessons, we think, from an animal that most of us know only as a languid resident of warm summer ponds. □

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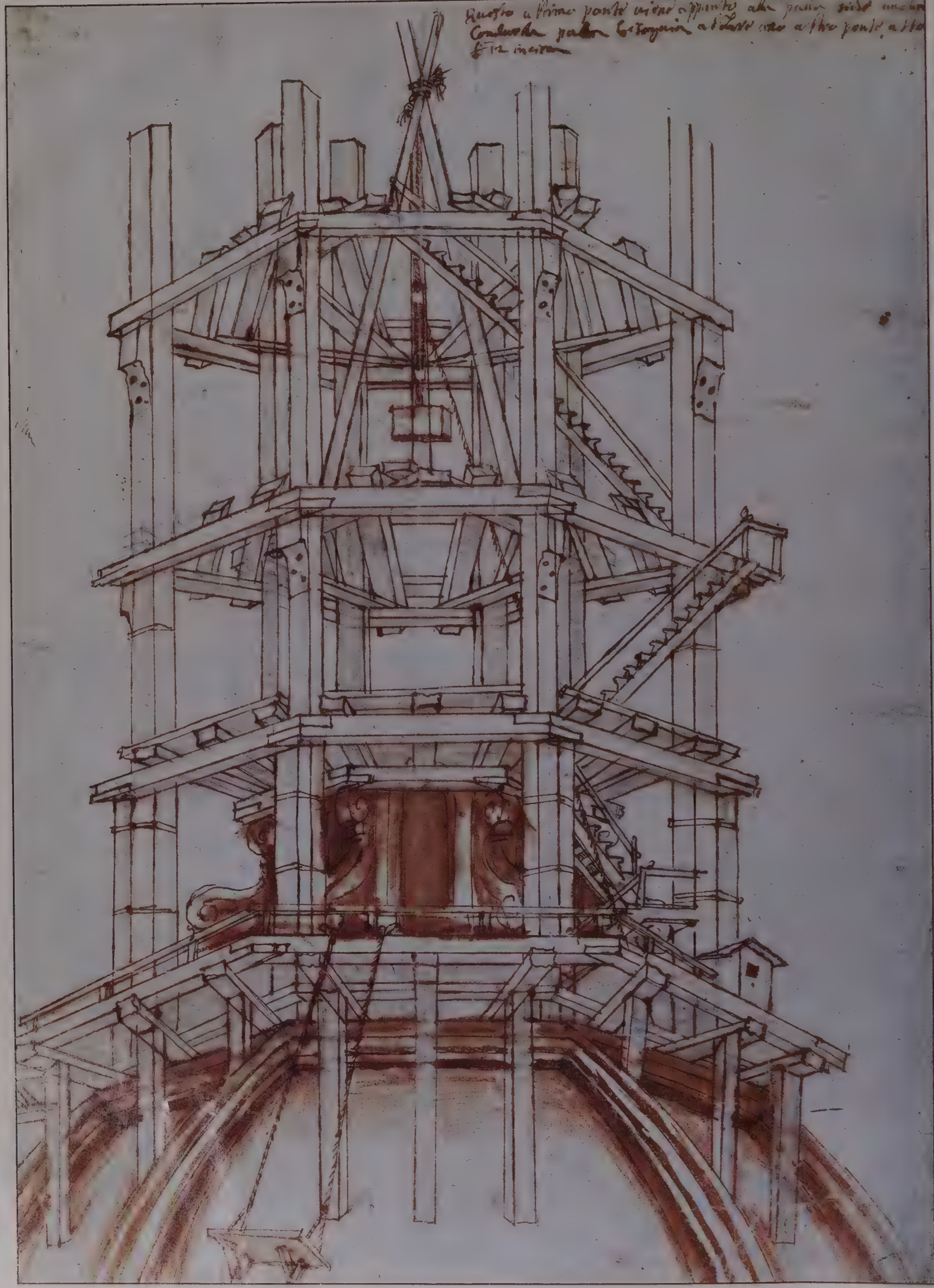

Columbus's Competition

In their search for the Orient, Europeans were bound to sail west

by Samuel M. Wilson

A few years ago I went on a modest quest in search of Paolo dal Pozzo Toscanelli, an archetypal Renaissance man and perhaps the foremost European geographer of the late fifteenth century. Toscanelli was convinced that by sailing west from the Atlantic coast of Europe, mariners could reach the rich trading centers of eastern Asia, and he encouraged Columbus and many other sailors to put the theory to the test. I wanted to see the astronomical device he designed for the vast dome of Florence's Cathedral of Santa Maria del Fiore to mark the summer solstice. Unfortunately, the bronze markers on the marble floor and window sills upon which light and shadow fall were closed off by maintenance work, so to get a look at them I headed up the one-way staircase to the top of the dome. I thought that the markers would be visible from the balcony one had to follow around the inside of the dome.

Crawling up the cramped staircase and making my way through a stone tunnel out onto the balcony, I suddenly realized that I was at a dangerous height above the cathedral's marble floor. The balcony railing was only thigh-high (the great architect Filippo Brunelleschi's way of making the extraordinary dome appear even higher); things must have seemed safer to the children who were screaming and running around my knees. With my back against the wall, I made it around the balcony, crawled up the masonry caverns of the dome's ribs to the top, then back down to solid ground. (Toscanelli's markings were covered with tarps and I never did see them.)

Toscanelli lived at a critical time. Europe's population was growing rapidly, the feudal system of the Middle Ages was dying, and the Italian Renaissance was breaking new ground in artistic expression. A growing class of urban traders and artisans, and a growing aristocracy, demanded the silks, spices, and gems of the Orient. But the flow of goods along the land-based Silk Route had been stemmed by events in the Middle East: European relations with the Ottoman Turks had deteriorated, and the region was still feeling the effects of the expansion of the Mongol Empire that had occurred in the preceding centuries. The most promising alternative to this overland route was by sea.

Among those with whom Toscanelli corresponded was Christopher Columbus, a merchant sailor from Genoa who had lived in Spain, Portugal, and elsewhere and who had been very active in Europe's expanding trade interests. Columbus had already been to Iceland and down the west coast of Africa. Now he was interested in finding a quicker route to Japan and China than the one the Portuguese had begun exploring around the southern tip of Africa. Believing, as did all educated Europeans, that the earth was spherical, Toscanelli encouraged Columbus's conviction that the fastest route from Europe to the Orient lay across the Atlantic:

> Paul, the Physician, to Cristobal Colombo, greeting. I perceive your magnificent and great desire to find a way to where the spices grow, and in reply to your letter I send you the copy of another letter which I wrote, some days ago, to a friend and favourite [Hernán Martínez] of the most serene King of Portugal before the wars of Castille, in reply to another which, by direction of his highness, he wrote to me on [the subject of sailing west from Portugal to reach the East Indies], and I send you another sea chart like the one I sent him, by which you will be satisfied respecting your enquiries [C. Columbus, *The Journal of Christopher Columbus,* Hakluyt Society, 1893].

Toscanelli's instructions were not confidential: he had been spreading this message for quite a while before his correspondence with Columbus. As early as 1474 he had exchanged letters with a Portuguese cleric attached to the Portuguese court and had recommended this western route over the proposed route around Africa, saying it was "a shorter way of going by sea to the lands of spices."

Columbus did not have any particular advantage over his competition. His ships were no better, and possibly worse. He based his understanding of the shape of the world on information that everyone else had access to (perhaps to his advantage, he interpreted this meager information incorrectly: he thought the world was much smaller than it was). So why did Columbus reach the New World ahead of his competitors? In part because of a few shrewd decisions, and to a large extent because of luck. Perhaps his most critical, or luckiest, decision was to sail by way of the more southerly Canary Islands instead of the Azores.

In the mythical versions of Columbus's first voyage, the vast and sinister Atlantic Ocean was completely uncharted, and Europeans left sight of land at their peril. In fact, islands lying far out in the North Atlantic were already known. Key to their discovery was the pattern of winds and currents off the African and European coasts. Ocean currents flow in a clockwise direction around the North Atlantic's perimeter: the Canaries current flows down the coast of Europe to the bulge of West Africa, the northern equatorial current crosses the Atlantic along the Tropic of Cancer, and the Gulf Stream races up the eastern seaboard and then drifts across to Europe. The winds push these currents along: the trade winds blow from east to west on the southern part of the circle and the westerlies bring the currents back to Europe.

Thus, sailing down the west coast of Africa was not difficult for fifteenth-century European navigators. The Canaries current and the trade winds were in their favor. On the return trip, however, they had to fight both winds and ocean cur-

The dome designed by Brunelleschi for Florence's Cathedral of Santa Maria del Fiore nears completion in 1436.
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rents. Portuguese mariners did two things to get around these obstacles. First, they built small, agile ships, called caravels, that could sail into the wind more easily and still take the Atlantic's pounding (Columbus's *Niña* and *Pinta* were examples). Second, they sailed west into the Atlantic, away from the coast-hugging Canaries current, before turning north. As a result, they found the Cape Verde Islands, the Madeiras, and the Azores.

From the late 1470s to the mid-1480s, Columbus himself lived on one of the Madeiras, more than 500 miles from Portugal and about 300 miles from the African coast. This uninhabited archipelago had been discovered in the early 1400s and colonized in 1425. Columbus married Dona Felipa Perestrello e Moniz, the daughter of the captain, or leader, of the island of Porto Santo. Their son, Diego, who was to figure prominently in the early conquest of the New World, was born there about 1480.

The Azores, a chain of [illegible] inhabited islands strung out between [illegible] and 1,000 miles from the mainland, were discovered in the 1420s, although how and by whom is contested. Historian T. Bentley Duncan has unraveled the myth and early documentary record of the Azores in *Atlantic Islands*. An apparently well-informed cartographer put them on a map in 1439 and in the legend said, "These islands were found by Diego de Silues, pilot of the king of Portugal, in the year 1427." The islands were stocked with sheep by other Portuguese in the 1430s by order of Infante Dom Henrique (Prince Henry the Navigator) and colonized about 1440 under the direction of Gonçalo Velho Cabral.

By 1450 the Azores were the most remote European outpost in the Atlantic. Getting there was a feat in itself. So if one wanted to sail west to the Far East, the islands seemed to offer a logical head start. One of the first to try this strategy was Ferno Dulmo, who lived in the group of the Azores called Terceira and had also heard Toscanelli's arguments. Dulmo's plan was to search first for Antilia, the semimythical "Island of the Seven Cities" that showed up on several maps as early as the late 1300s.

Dulmo applied to the Portuguese king, Dom João II, for permission to sail west to look for Antilia. The Portuguese government contributed no money to the venture, and Dulmo demanded no specific rights and titles for lands he might find (making him a far cheaper alternative than Columbus, who asked for money, perpetual titles, shares in potential profits, and so on). Nevertheless, the king promised Dulmo suitable recompense, honors, and titles if he was successful.

Teaming up with João Estreito, a capable and ambitious sailor from the Madeiras, Dulmo sailed west from the Azores for forty days, longer than Columbus sailed on his first voyage to the New World. But because the Azores lie at a latitude where the westerlies blow, Dulmo sailed into the wind and into the Sargasso Sea, a vast floating morass of seaweed lying between the Azores and the Caribbean. After getting a long look at the middle of the Atlantic Ocean, he returned, having found nothing.

One of the maps that Dulmo used as a guide was drawn by a young German named Martin Behaim, an ambitious geographer and sailor who operated in the

Brunelleschi's dome dominates Florence, in a painting by Gaspare Vanvitelli (1653–1736).
Scala/Art Resource

same circles as Dulmo, Estreito, and Columbus (they probably all knew each other personally, and certainly knew of each other). Behaim was a member of Portugal's Royal Maritime Commission—the committee that decided whom to sponsor on what voyages—and had already been knighted by the king. He too had a connection to the remote Atlantic islands, having married the daughter of the captain of the island of Fayal in the Azores. And he too had dreams of sailing west from the Azores.

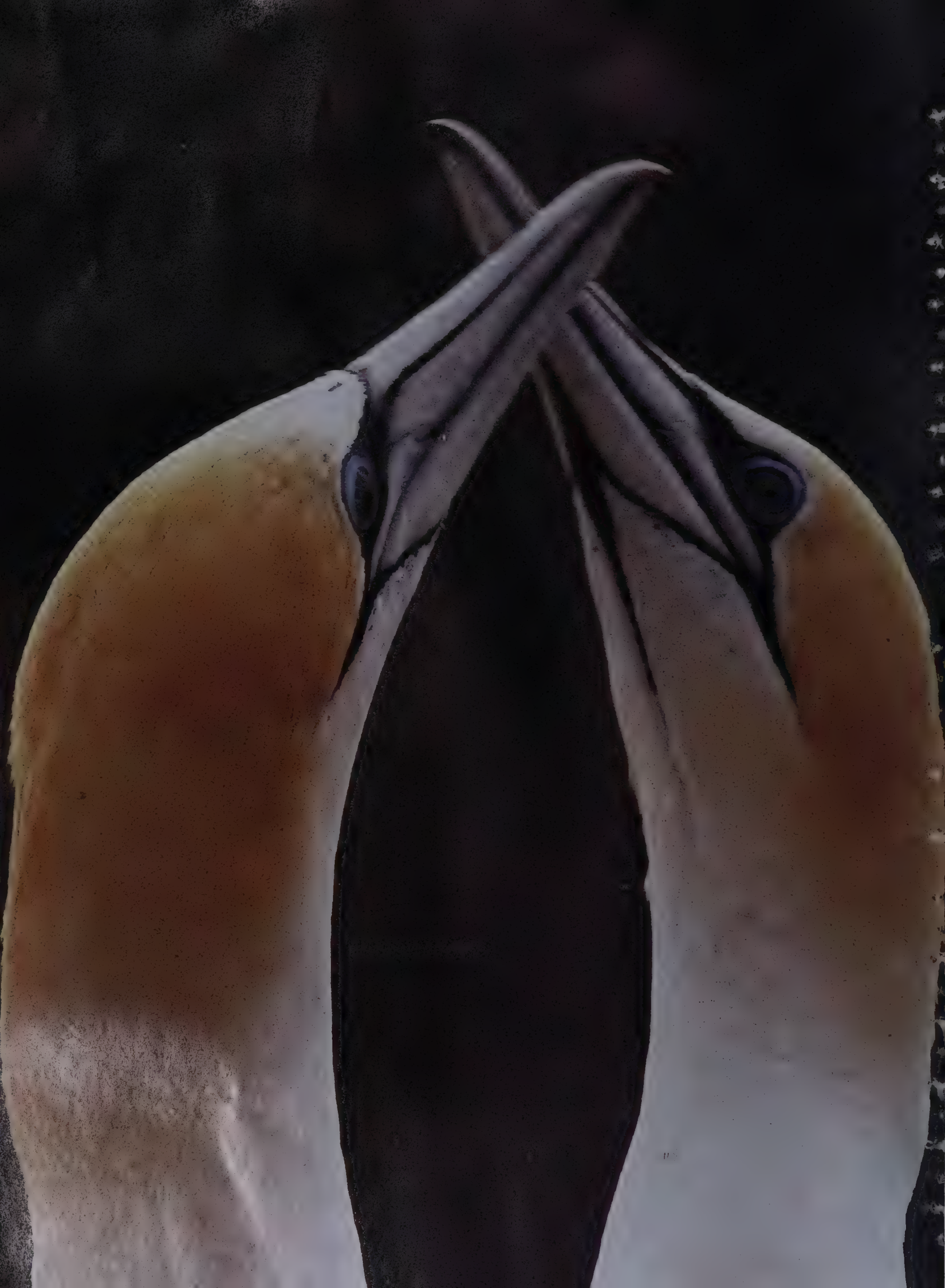
Behaim had been trying for years to get the Portuguese king to give him ships and royal sponsorship. In 1493, after Columbus had returned from his first voyage but before anyone had heard the news, Behaim had the most famous astronomer of his home city of Nuremburg write the Portuguese king and plead his case:

> You possess means and ample wealth; as also able mariners, eager to acquire immortality and fame. O what glory you would gain, if you made the habitable Orient known to the Occident, and what profits would its commerce give you, for you would make those islands of the Orient tributaries, and their kings amazed would quietly submit to your sovereignty! . . . And furthermore, our young man Martin Behaim is ready to take charge of such a voyage and set sail from the Azores whenever you say the word [S. E. Morison, *Admiral of the Ocean Sea,* Little, Brown, and Co., 1942].

But Behaim's plans were overtaken by Columbus's discovery under Spain's flag. Columbus was the first to make it to the New World because—whether by luck or experience gained in his years at sea—he was the first to try the southern route. To go from the Azores westward, even though it was closer, was nearly impossible because of the winds. Columbus went far enough south that the easterly trade winds were in his favor and the north equatorial current carried him along.

That Columbus had close competitors—the figures mentioned and others known and unknown—suggests that even if his voyage had ended in failure, the arrival of European ships on the eastern coasts of the Americas was inevitable. Would the past 500 years of culture contact have turned out differently if Ferno Dulmo had arrived first, landing on the coast of what is now Virginia? The possibilities for speculation are endless. For that matter, what would have happened if instead of landing in the Bahamas, Columbus had landed on Mexico's Gulf coast and seen the Aztec empire at the height of its power? Columbus would have been more convinced than ever that he had reached the Orient. But he and his colleagues might well have been killed as threats to Aztec power, and the impact of Europe's expansion on the people of the New World would have been delayed for a few more years.

Samuel M. Wilson teaches anthropology at the University of Texas at Austin.



In an exuberant greeting display, a pair of Australasian gannets fence with their bills. Such ritualized behavior reinforces the birds' lifelong pair bond.
Erwin and Peggy Bauer

The Gannets of Cape Kidnappers

Masters of body language, these Southern Hemisphere seabirds have developed an accent slightly different from that of their northern cousins

by Bryan Nelson

The cold and sullen waters of the North Sea swirl around the unyielding basalt of Bass Rock, an ancient volcanic plug off the east coast of Scotland and a classic nesting site of the northern, or North Atlantic, gannet. Between November and February, the North Sea, the "ganet bath" of the early seventh century Anglo-Saxon poem *Beowulf,* experiences freezing gales and vast, frothy seas smoking with spray. Yet by January, after four or five months spent feeding at sea, the gannets are back on the cliff ledges on which they will nest. They commence the breeding season with ample fat reserves, as the inhabitants of Saint Kilda well knew. An island in the open Atlantic to the west of the Scottish Hebrides, Saint Kilda was inhabited for more than a thousand years by islanders who lived almost exclusively on the seafowl, largely gannets and fulmars, that swarmed around the island's crags and cliffs.

At the other end of the world—at Cape Kidnappers on the east coast of North Island in New Zealand—lies another famous gannetry. The antipodean gannet closely resembles its Northern Hemisphere relative in appearance, behavior, and ecology. But however similar they seem, they have inevitably evolved different adaptations to their environments. To compare them, I traveled from Scotland to live for a season at Cape Kidnappers.

The cape is a fine sweep of gleaming silver mudstone forming the southern horn of Hawkes Bay. (The cape is so named because when an English draper from Yorkshire turned navigator—the indomitable Captain Cook—was charting the coast of New Zealand, Maoris attempted to kidnap one of his ship's boys.) Erosion has breached the slender tip of the peninsula, leaving an isolated beehive-shaped stack too small to hold gannets. But at the extremity of the horn, in a deep saddle, lies a superb gannet colony. A second group of gannets nests on an adjacent plateau and a third on the Black Reefs, eleven tiny rocks half a mile from the main colony. Altogether, Kidnappers holds 5,000 to 6,000 pairs of gannets (there are some 26 colonies and 46,000 pairs of Australasian gannets in the total world population). Gannets seldom nest on the mainland; usually they choose small, offshore islands, but the cape is nearly an island. Compared with the colony on Bass Rock, first recorded in the seventh century, the Cape Kidnappers gannetry is recent. The saddle was probably occupied by 1879, the plateau about 1936, and the Black Reefs two or three years later.

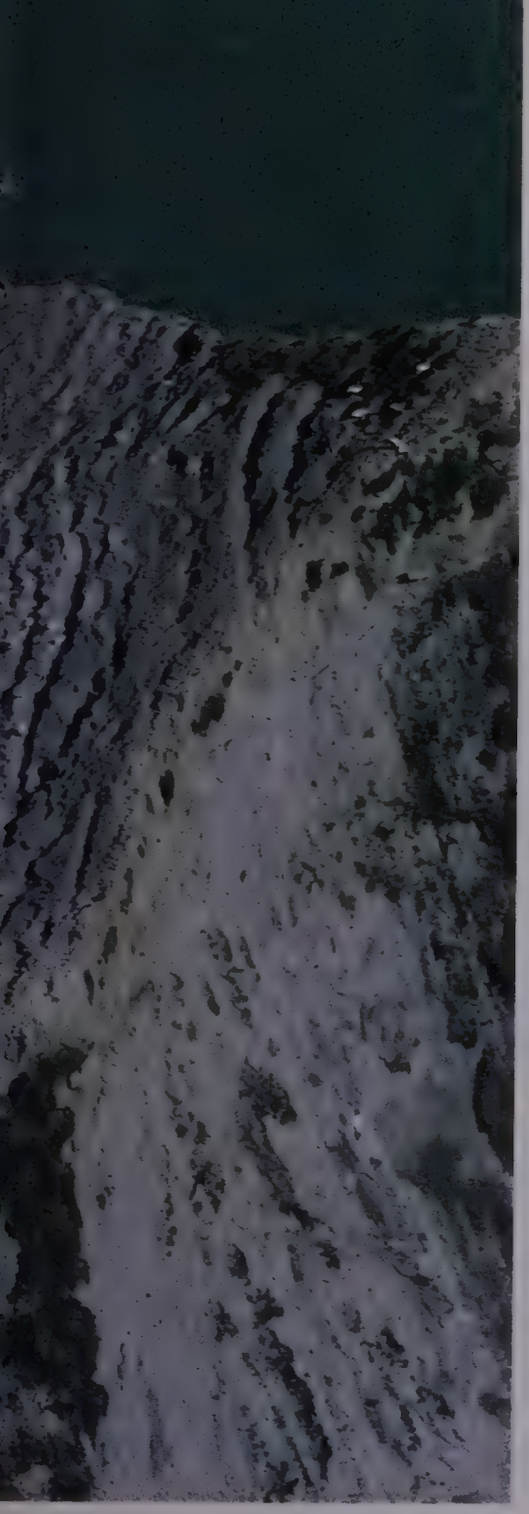
I went to the Kidnappers colony with high expectations and a long list of questions suggested by twenty years of observations at the great Bass Rock colony. Mainly, they were questions about social behavior, for I had long been fascinated by the innate sign language, or displays, by which gannets communicate with one another, thereby insuring the efficient functioning of the colony. Without clear communication, a teeming colony would look and sound like pandemonium. In fact it is a well-ordered chaos. Considering the many complicated messages that a gannet is required to send and to receive if it is to breed successfully, one gains a healthy respect for the efficiency of the birds' "instinctive" communication system.

Armed with binoculars, stopwatch, tally counter, notebook, and video camera (a powerful tool for immediate playback

of behavioral sequences in the field and later extraction of data), I sat down at the edge of the colony and began watching the birds. It was a typical Hawkes Bay spring day, with a warm sun and sparkling sea. At my very feet were the massed ranks of three-foot-long, dazzlingly white seabirds with rich buff heads and necks, blue eyerings, gray-blue bills, and black wingtips. The colony pulsed with frenetic activity and an almost palpable din hung in the air—a high-pitched gabbing utterly distinct from the harsh hubbub of northern gannets but with equally significant physiological effects on the participants. Every now and then a series of rapid, high-pitched notes pinpointed an inflying male gannet en route to his nest; the female's voice is deeper. With gannets packed together at a density of two to three pairs per square yard, and with no natural landmarks for pilotage, mistakes were inevitably made by incoming birds and vigorous attacks were visited upon inadvertent intruders.

Fights were, in fact, one of the first things I wanted to watch in order to estimate their frequency, intensity, and duration. Northern gannets are outstandingly aggressive birds when establishing and defending their territories, which are merely nest sites plus about as much space as they can dominate while sitting on the nest. Primarily adapted for nesting on cliffs, northern gannets possibly competed fiercely for such sites in the past, when populations may have been much greater than they are now. Also, northern gannet pairs that manage to lay early in the season are more likely to produce offspring that will themselves survive to breed. Acquiring a site near or among established birds means greater exposure to social stimulation, which in turn prompts earlier laying. Both of these factors may have been involved in the evolution of the Atlantic gannet's strong sense of territory.

Australasian gannets, in contrast, are mainly flat-ground nesters with a much more variable mean laying date (that is, roughly, the date averaged for the colony as a whole). I thought that perhaps here in New Zealand, competition for sites, and therefore aggression, would be less intense. This turned out to be the case, although watching the ferocity with which intruders were attacked, one could be forgiven for doubting it. But fights are usually brief affairs, lasting just a minute or two, and are usually the result of inadver-



Flat-ground nesters, Australasian gannets in the dense saddle colony of Cape Kidnappers in New Zealand evenly space their nests, left. Northern gannets are cliff nesters. Parents and their single offspring nest precariously on the narrow cliff ledges of Bass Rock off the coast of Scotland, below.

Photographs by Bryan Nelson

tent trespass rather than genuine competition for a site. The nest itself is composed mainly of guano, which sometimes forms a considerable mound; detritus, seaweed, and other vegetation may be added.

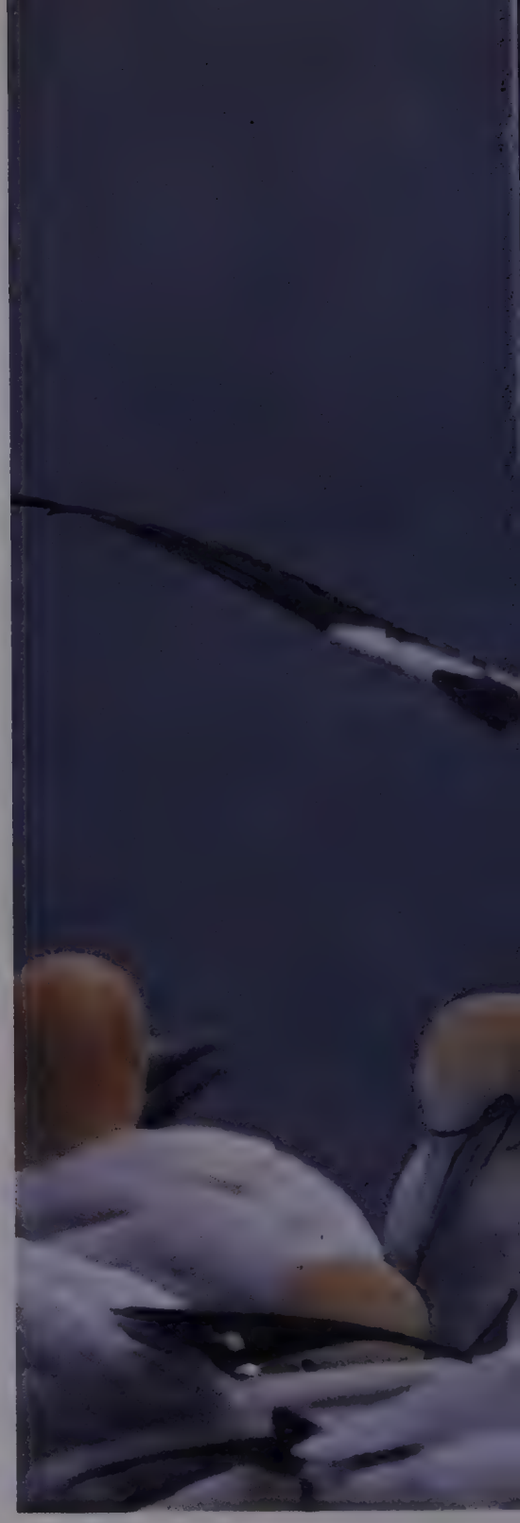
Fighting gannets call stridently, but much of the hubbub from the Kidnappers colony came from displaying gannets, both male and female, proclaiming their ownership of a site. They alternately sweep their head and neck downward and raise and shake their head from side to side, all the while holding their wings partly out from the body and slightly cocking their tail. At the end of the display their bill-tip is pressed against their upper breast and held there for a second or two. Again and again, a bird standing relaxed on its nest pedestal would suddenly lengthen its neck, shake its head, open its wings, and launch into this bowing, or curtsying, display. This territorial behavior is motivated by aggression and provides a good basis for comparing the Cape Kidnappers gannets with the Bass birds.

The evidence for the aggressiveness in bowing is twofold. Contextually, the display is always performed by the victor after a dispute. No matter how filthy, bedraggled, and even bleeding he or she may be, a victorious bird will bow again and again on the hard-won site. A vanquished one never does this. Any threat of intrusion, such as a fracas in the neighborhood, will elicit bowing. The act itself indicates redirected aggression: biting directed to the ground. The ritual does not usually involve actual biting of the ground, although in the early stages of its performance on a new site it sometimes does. But soon, sometimes within hours, it becomes "polished," the ground biting being represented by the downward sweep of the head. Nevertheless, the display retains its aggressively motivated message: "Keep out." When the Australasian gannet "bows" it performs fewer of the ground-biting movements than does the Atlantic bird and holds its wings closer to the body. This lower-intensity version of territorial behavior, like the lower-intensity fighting, suggests less overall aggression.

One of the most interesting manifestations of the northern gannet's territorial aggression is the attack of the male upon his mate each time they reunite, regardless of whether he is the incoming partner or the one on the nest. When the pair are but newly met, his attacks are so violent and unremitting that casual observers could be excused for thinking they were witnessing a particularly one-sided fight, for the female does not retaliate but merely appeases by presenting her nape to be bitten. (The classic ethological explanation for this behavior is that the female, outwardly identical to the male, looks like a possible interloper and thus triggers his territorial aggression—which she must then defuse.) Australasian gannets behave similarly, but males are much less likely to attack their mates. The form of the behavior is identical in the two species; it is merely the intensity and frequency that differ.

The next item of behavior I wanted to check was copulation. I didn't have to wait long, for in the period before egg laying, gannets mate frequently, although once the single, chalky egg is laid, copulation ceases so abruptly that I have observed a male checked in the very act of mounting by the sight of the newly laid egg. As a prelude to and during copulation, the

Gregory G. Dimijian



Preparing for takeoff, an Australasian gannet, below, signals its intention by sky pointing with its bill. A northern gannet, right, stretches its wings wide in a prelude to feather ruffling and shaking, a grooming measure.

Erwin and Peggy Bauer

males at Kidnappers, like my birds on Bass Rock, gripped a female's nape forcibly and occasionally jabbed and shook her for good measure. This was yet another manifestation of the aggression, combined with sexual behavior, that the female elicited from her mate. The act of mating lasted on average for twenty-six seconds, which like that of the northern gannet, is four or five times longer than that of most seabirds of similar or even larger size, such as pelicans or cormorants.

In most seabirds, including gannets, copulation serves not only to inseminate but also to strengthen the pair bond and hasten the maturation of the eggs. Gannets begin to mate long before an ovum is actually ready for fertilization. I suspect that lengthy copulation in the gannet is associated with the unusually strong element of aggression between the partners and that the two elements, sex and aggression, have become positively reinforcing—in some way attractive—for the female. Otherwise, an overtly aggressive male that would be successful in acquiring a competed-for territory might be unsuccessful in retaining a mate because of his forceful attacks on her. But if aggression were a rewarding component of copulation—and indeed of other sexually motivated behavior, such as the greeting ceremony—then the two motivations, sex and aggression, would act in concert rather than in opposition.

The Cape Kidnappers gannets are so thoroughly conditioned to visitors that they allow an extremely close approach. The way in which the egg is incubated beneath the webs of the feet, for instance, can be observed at close quarters. In some respects this unusual but effective incubation method seems better than that of the related cormorant, which incubates its clutch on top of its huge black webs and as a result often kicks an egg out of the nest when departing. But gannets subject the egg to heavy pressure and probably as a consequence have evolved two habits. First, they probe the bottom of the nest cup to locate any stones or hard lumps of earth or flotsam, which they then fling aside with the same violent head movement that they use to shake unwanted fish fragments that stick to their bill. This, incidentally, brings up an interesting general point, which is that sometimes gannets use the same simple behavior pattern to carry out two different tasks, yet at other times they neglect to use an existing habit to perform an act that would be of significant advantage to them. For example, I observed a small chick that had been displaced from its nest during a fracas. Its parent simply needed to pick it up as if it had been a piece of nest material and place it back in the nest. The parent possessed all the neuromuscular equipment required, but instead it left the chick to die. Similarly, Abbott's booby, a member of the gannet family, which nests in the jungle canopy of Christmas Island in the Indian Ocean, uses its powerful bill to break off twigs for building the nest. But if it falls into a dangerous position among the branches, it does not use that same, twig-grasping movement to pull itself back to safety. Instead, it awkwardly attempts to lever itself upward. Precisely because so many of the adaptations of animals are complex and perfect, we perhaps tend to forget that, sometimes, adaptations are grossly imperfect or absent altogether. The other habit related to under-the-web incubation is that once the egg has "pipped," and the shell is therefore weakened, the gannet transfers it to the top of the webs. Failure to do so results in a squashed, half-hatched chick, a fate that actually befalls a small but significant proportion of the chicks of inexperienced breeders.

Male and female Kidnappers gannets share incubation about equally. When the off-duty partner returns from its foraging trip, usually after about twelve hours at sea, the pair perform an ecstatic greeting ceremony. One of the great bird displays, ranking with the dance of the albatrosses or the triumph ceremony of geese, it is the very epitome of a reunion. Standing breast to breast with their wings out, the partners call stridently and fence with their bills, occasionally reaching downward over each other's necks. This is a pair-bonding

display, but I observed that the greeting ceremony of the Australasian gannet is shorter and contains fewer bowing movements than that of the northern gannet, that is, fewer aggressive components are incorporated into the display.

Every few minutes a minor commotion in the colony drew my attention; if it wasn't a bird landing in the wrong place and frantically trying to relocate, it was one trying to depart. Gannets, unless in a panic, take some time to work up to departure. This is adaptive because of the danger of leaving an egg or small chick unattended in the crowded colony. By signaling its impending departure, a bird and its partner can coordinate their behavior accordingly. So, before flight, the gannet adopts a peculiar "sky-pointing" posture and gyrates slowly around, lifting its webs high in a ritualized, in-place walk. The commotions I witnessed arose when a departing bird finally had to make its way through the crowded colony and was attacked on all sides. Evidently the preflight posturing did not effectively secure unmolested passage through the ranks. I believe that its actual function is to emphasize the intention of departing and thereby to inhibit the sky-pointing bird's mate from simultaneously leaving the nest. In this way, cooperation is achieved and one bird always remains to thwart predatory gulls or pilfering fellow gannets. One partner is almost always keener to depart than the other so that no conflict of intent ensues, but sometimes a great deal of mutual preflight posturing by both of them is required before one backs down and the other leaves. I found such battles amusing and instructive to watch and always tried to predict the outcome. The Kidnappers gannets nest on flat ground, and once they reach the edge of the colony they have a good runway, but the cliff-nesting northern gannets, which can simply step off the ledge, still sky point just as much. This is more evidence that the function of sky pointing is not appeasement, since in the northern gannet's case, there is often nobody to appease.

Sky pointing probably arose from the normal neck lengthening by which a gannet prepares for flight. Simple behavior patterns such as neck lengthening, walking, or shaking water off the bill commonly become elaborated or exaggerated and end up as components of ritualized display or at least serve as signals. One common habit of the gannet is wing

Trespass, however inadvertent, into the wrong neighborhood of a crowded colony leaves a gannet open to attack by the territory owners.

Photographs by Bryan Nelson

shaking, performed when the plumage is wet, soiled, or in disarray. But it is also enacted when the gannet is alarmed and is preparing for flight. Since a certain background level of "anxiety" constantly exists in a gannetry, simply as a result of the breeding birds' vulnerability on land, background level wing shaking is always evident. This makes it a useful indicator for anxiety, and systematic checks of its frequency show that wing shaking peaks early and late in the breeding season but drops in midseason, when the motivation to incubate eggs and care for chicks predominates.

Preening is another simple gannet act that has acquired the secondary function of pair bonding. Mated birds usually follow their meeting ceremony by preening each other on the head and neck. At first glance the actual act—the movements of the mandibles—appears to be identical to self-preening. But in fact the motivation is probably not that of ordinary preening. If you watch a new pair closely, you will notice that the preening is abnormally rough. Indeed, it may occasionally grade into actual biting and then revert to preening. The lovey-dovey "kiss preening" seems to be a sublimated form of aggres-

Intensely territorial, gannets use bowing, a biting motion directed toward the ground, to warn other gannets to keep away from their site. Bowing by one bird stimulates neighbors to do the same.

sion, which is entirely consistent with the dual nature of the greeting ceremony and the preceding nape biting. Since they are more aggressive than Australasian gannets, we might expect that northern gannets' mutual preening bouts would be longer, as indeed they are.

Does adult aggression have anything to do with parental behavior? Probably quite a lot. The juvenile gannet's plumage, which it attains at the age of ten or eleven weeks, is strikingly different from that of the adult. Late in the breeding season, the Kidnappers colony is a pattern in black and white. On each flattened nest pedestal sits a black youngster (but with pale belly and white speckles on the back) as large, and with the same posture, as its pristine white parent. The picture is the same with the birds on Bass Rock, except that the Atlantic gannet's young are much blacker than the Kidnappers birds. What has this to do with aggression? Imagine what might well happen to a young Bass gannet confined to its precarious ledge if the incoming male should attack it as vigorously as he sometimes attacks his mate. I have filmed a male knocking his mate clean off the nest. A single such incident directed to the juvenile, as yet unable to fly, would guarantee its premature demise. Its juvenile coloration, by being so very different from the adult's, reduces the likelihood of an attack. In addition, in an appeasement gesture the chick hides its bill by turning it away or, in extreme cases, tucking it beneath its belly, although such a gesture would avail little against the paternal thunderbolt from the blue.

The young Australasian gannet is in less danger; it resides on flat ground rather than a narrow cliffside shelf, and its father is less aggressive. This may be why it is considerably paler (that is, more adult-like) than the northern juvenile. In addition, when the young gannet begins plunge diving for fish, the pale breast and belly also serve as good camouflage, making the bird harder for the fish prey to discern against the light sky.

Young gannets at Cape Kidnappers are fed about twice a day, and in 13½ to 15½ weeks they grow from hatchlings of about four ounces to fledglings of up to seven pounds, or about 140 percent of adult weight. In the colony, closely packed nests and the adults' formidable bills are adequate safeguards against predators, such as the southern black-backed gull, but wet weather can cause heavy loss of life if it comes when the chicks are too big to be brooded but still downy. Usually, however, overheating is more of a problem than chilling. One way the young cool off is by excreting onto their feet and then exposing them to the sun, where evaporative cooling lowers body temperature.

Day after day, the chicks swelter on the plateau as the Hawkes Bay sun climbs into clear blue skies. The baked earth of the colony, white with guano, becomes littered with molted feathers and here and

Gannets engage in lengthy and frequent copulation before the single egg is produced. Aggression is an integral facet of copulation, with the male forcefully gripping and shaking the female by the nape.
Erwin and Peggy Bauer; Bruce Coleman, Inc.

there the dried carcass of a chick or even an adult, and one's nose registers—in my own case with pleasure—the distinctive odor of a seabird colony. Gone is the orderly appearance that characterized the colony in the early days, when the lines of incubating adults seemed geometrically precise. Now the colony is a bustling nursery. Soon the young gannet sheds its down for a set of feathers and is ready to fledge. At this point, northern and Australasian gannets behave slightly differently. The former fledge in a single, irrevocable act by leaping from the cliff ledge and flying out to sea for perhaps two miles or merely a few yards if their descent is sabotaged by treacherous downdrafts. This first flight, which I have witnessed on many occasions, is usually erratic and understandably ill-coordinated; a few attempts end disastrously as the heavy youngster on untried wings loses all control and crashes at the base of the cliffs.

The northern gannet parents totally ignore the offspring once it leaves the nest, condemning it to the hazards of completely unaided transition to independence, a challenge failed by more than half of the fledglings. The Australasian gannet, in contrast, fledges in stages, by making its way to the edge of the colony, practicing short flights, and returning once or twice to the nest to be fed. Australasian adults are sufficiently unaggressive to make it possible for the fledgling to travel from its nest to the edge of the colony and back again. Even if topography allowed, the aggression of adults would prohibit this in the northern gannet. Indeed, I have more than once seen fledglings prevented from reaching the cliff edge by the attacks of intervening adults.

I found the Australasian gannets' practice of feeding their chicks several times during the fledging process of great evolutionary interest. Northern gannets show a total disregard of youngsters once they have left the nest, a situation unique among gannets and their close relatives the boobies. All species of boobies are known for their prolonged parental feeding of fledglings. The Australasian gannets' feeding schedule formed a link, an intermediate step, between the two extremes. This suggested to me that the Australasian gannet is nearer to the ancestral gannet/booby stock than is the northern, and that the northern gannet is derived from an Australasian ancestor. This scenario is supported by the existence of a geographically intermediate population of gannets in southern Africa—the Cape, or African, gannet—which closely resembles the Australasian birds, and by the migratory patterns of the three gannets. Cape Kidnappers juveniles usually migrate across the Tasman Sea to the east coast of Australia, but a few overshoot westward and end up among the African birds. Similarly, some African gannets on their way north to the Gulf of Guinea fly too far, appearing as far north as the Mediterranean and even off Scotland.

The Northern Hemisphere birds have acquired greater size, weight, and fat deposits, and a more consistent mean annual laying date as adaptations to the cold, rough waters and powerful shoaling fish, such as herring and mackerel, of the North Atlantic. There, because of predictable oceanographic features, fish movements and hence gannet feeding opportunities tend to be equally consistent. Thus, laying dates are coordinated to produce chicks at the most propitious time. Competition for cliff sites and for "social" sites that help them to lay at the optimal time of year favored the evolution of aggression. The more aggressive individuals would presumably have a better chance of acquiring one of the limited number of topographically and socially adequate sites. The Australasian gannet is not subject to the same set of selection pressures; egg laying is less seasonally consistent and adequate nesting sites are plentiful.

Although they nest a world apart, northern and Australasian gannets have exactly equivalent behavior, the only differences being subtle shifts in the frequency and intensity of those components that have their roots in aggression. This theory, supported by some circumstantial evidence, is, like all theories, put forth to be tested. I hope that anybody who tests it by field observation enjoys his or her thousands of hours with gannets as much as I have. □

GALÁPAGOS SURF AND TURF

During mating season, male marine iguanas forgo their peaceful ways to defend beach-front property

Text and photographs by Carol R. Townsend

The marine iguanas of the Galápagos are among the few seagoing lizards in the world but never venture far from the black volcanic rocks of the islands' shores. Often piled two or three lizards high, they bask in the hot equatorial sun to raise their body temperatures before wading into the cool ocean waters to feed. While in the water, their body temperatures may drop as much as 18° F. The iguanas browse on algae, which grow in abundance on intertidal rocks and shallow reefs. Excellent swimmers, the lizards use their long, muscular tails to propel themselves through the water and can go as deep as thirty-five feet for a meal.

When the breeding season starts, adult males become intolerant of one another and leave the groups to establish territories, which they patrol. The males court and attempt to mate with female iguanas that enter their territories, while excluding other males with ritualized displays and fighting. The best territories are above the intertidal zone near sandy

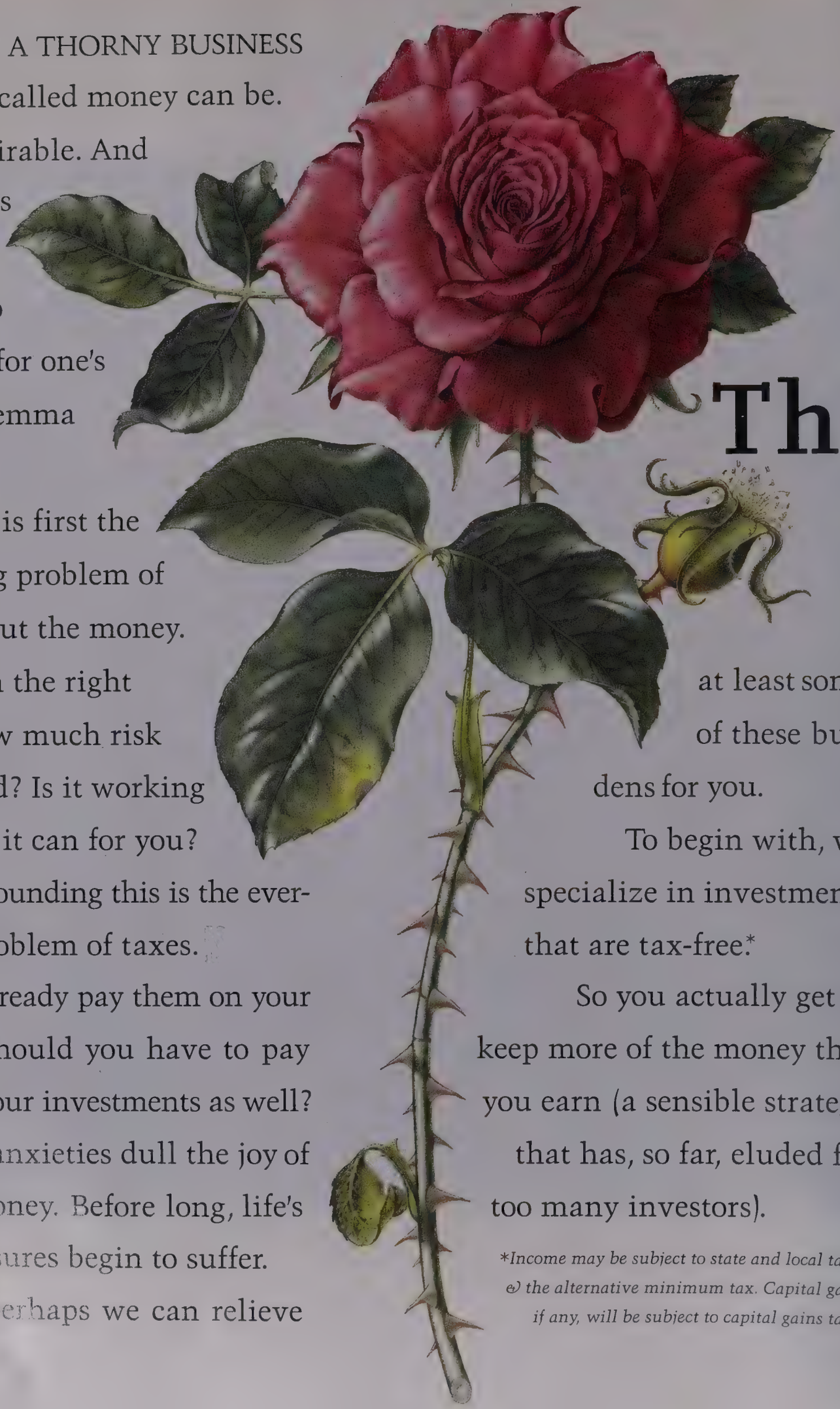
For most of the year on Isla Santiago, marine iguanas, top, bask peacefully in the sun. During the breeding season, however, males, above, engage in territorial disputes. Right: During a shoving match, males lash each other with their powerful tails.

areas where female lizards will dig nests and lay two or three eggs. On some islands these nesting sites are very limited.

When two males confront each other at a territorial boundary, a lot of posturing occurs. One male will present himself broadside to the other, standing high on his legs, with crest erect and body inflated. The iguanas rapidly nod their heads, as if shuddering, and gape, displaying red-tipped, fleshy tongues. If the intruding male does not retreat, they face each other, continue nodding their heads, and then charge with heads lowered.

Grabbing with large claws for a hold on the rough terrain, the lizards push each other with the spikelike scales that adorn their heads. The shoving match is frequently interrupted by further displays and may last several hours. Occasionally, an aggressive iguana may bite his opponent on the jaw, legs, or crest and shake him violently. Most battles, however, are settled without serious harm to either lizard; eventually, one will either move away or assume a submissive posture, lying flat on his belly. □

In a confrontation, facing page, a male rises up on his legs, broadside to his opponent. Below: A male straddles a female as they mate. Normally a dull black, males may turn a mottled green, tan, or blood red during the breeding season. A crust of salt coats the iguanas' backs and spines. Excess salt, ingested with their food, is removed from the blood by a gland that opens into their nostrils. Periodically, the lizards "sneeze," expelling a salty solution that settles on their backs.



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Wearing bark-cloth masks, dancers representing monkey spirits make their way to a ceremonial long house.

Dance of the Water People

Gold mining threatens the world of a Colombian Indian shaman

by Kaj Århem

After a midnight break for refreshment, a long line of Makuna Indian dancers reenter the long house, their heads covered with reddish bark-cloth hoods and black-and-yellow face masks made from dried and painted tree resin. Their long-sleeved shirts of bark cloth and their skirts of dried bark strips rustle as they move. They dance alternately in lines and in a circle; it is a solemn, monotonous dance accompanied by a melancholy tune. The dancers represent the fish spirits, or the "fish people," and the song recounts the seasonal migration of the *sabaleta* fish (a species of *Brycon*) from feeding grounds in the headwaters of the Komenya River to spawning grounds in the Apaporis River—the two rivers that define the territory of the Makuna in the rain forest of eastern Colombia.

The long house, lit only by torchlight, is crowded with spectators. Men, women, and children sit on stools or lie in hammocks along the walls. The masked dancers are all men, but after a while women join in. The red hoods and painted masks glow in the moody torchlight, then fade into strange silhouettes. The loud chorus of fifty men, the stamping of a hundred feet, and the rattles and throbbing tube drums combine to give the impression, as night wears on, that the dancers really are spirits from another world.

The dancing continues with brief interruptions for two full nights and days. The solemn dance of the fish spirits alternates with more playful performances of other animal spirits, with differently designed hoods and masks. The movements and songs of the dancers evoke the behavior of the various animals: jaguars and anteaters, frogs and beetles, bees and deer, river birds and many others. Toward the rear sits Ignacio, the shaman, unpainted and without costume, inconspicuously directing the Spirit Dance.

I first lived among the Makuna from 1972 to 1974, staying most of the time in Ignacio's long house. At that time the Makuna lived in about fifteen widely dispersed long houses, each forming a self-sufficient settlement. These communities had little regular contact with the Colombian society at large. There was no mis-

sion, no school, and no shop in the area, and very few Indians had even a rudimentary command of the national language, Spanish. Most had only a vague notion of belonging to a Colombian nation at all. The government was—and still is among older people—perceived as a powerful chief living in a big stone long house in a distant land called Bogotá. Life followed an ancient rhythm: men hunted, fished, and cleared and burned the forest for the gardens; women planted, tended, and harvested the crops—except for two traditionally male crops, coca and tobacco.

When I returned in February 1988—after almost fifteen years—I was struck by many changes. Instead of scattered long houses along the river, there are now three villages of single-family houses, although five big long houses remain in the area as ritual and political centers. Ignacio's long house is in the village of Santa Isabel, whose name reveals the strong influence of the Catholic mission during the past few years. Each village has a small chapel and a school, built by the villagers from local materials—mud, sticks, and palm leaves.

A new political and administrative order has been superimposed on the traditional authority structure. Now each village has an official headman, a village teacher, and a *catequista,* who performs a simple Catholic ceremony on Sundays. Like traditional headmen, the village headmen have influence in the community, but their duties are new: they have to mediate between the village and the world of the whites, negotiating with the authorities and making regular journeys to the regional capital of Mitú—about two weeks away on foot or by canoe.

Yet the people who welcomed me at my return were the same ones who bade me farewell fifteen years earlier. This, I felt, was significant: not only had the Makuna escaped the worst pressures of the national society, but they also had chosen to remain in their ancestral territory despite the attractions and opportunities offered by the outside world. I learned that in the intervening years, several young men had spent long periods away from the villages, working for rubber and coca bosses, but all had returned. They had married and settled according to traditional norms, which state that a man should marry a cousin—his father's sister's daughter or mother's brother's daughter—and stay close to his father's house.

In the early 1980s the coca trade had swept through the Colombian Amazon and heavily affected Indian groups in the region. Money and trade goods had flowed into Makuna society for a few bustling years, as most young and middle-aged Makuna men became involved in producing coca leaves. But in the mid-1980s, after a fall in producers' prices and increasing pressures from the military and the Catholic mission, the coca bosses left the area, and the trade vanished as quickly as it had begun. For a while, life returned

The shafts dug by gold miners, left, threaten not only to disrupt Makuna society but also—Makuna elders believe—to weaken the posts of the cosmic long house. Below left: A wooden cross commemorates a victim of mining-town violence.

Joe LeMonnier

to the old rhythm of hunting, fishing, and gardening for subsistence.

Then a new force began to threaten the Makuna world: gold mining along the Traíra River, only a few days' walking distance away. Gold was found on the Brazilian side of the river in the early 1980s, and on the Colombian side in 1986. In a matter of a few months, gold miners and adventurers began traveling to the area by river and trail. Many passed through the village of Santa Isabel.

In 1987 there was already a floating mining population of at least 5,000 along the Colombian side of the Traíra River. Soon mining towns grew up in the middle of the forest. In early 1990 I paid a visit to one of them, Cerro Rojo—"Red Hill." It has a ramshackle hotel, plenty of street-side shops, bars, and brothels. Until 1989, one of Colombia's many armed guerrilla groups (the FARC) ruled the mining area, but recently the government has established control over the region. The presence of the government in Cerro Rojo is now signaled by an airfield, a military post, a health station, and a school.

Yet order is precarious and elusive in the mining area. The towns grow without control, the forest is progressively cleared as new miners arrive, and houses—simple frames of poles with plastic or tin sheets for roofs—are erected almost overnight. Miners spend weekdays working in the gold fields—panning in shallow streams, scraping and sifting the topsoil, and most recently, cutting tunnels into the hillsides. On weekends they gather in the towns to

Makuna women, below, squeeze juice from the peach palm fruit to serve at the Spirit Dance. Fish spirits with painted masks and other costumed dancers, right, take a break to consume the drink prepared by their human hosts.

shop and socialize, and to drink and dance in the local bars. The dream of making a fortune and the possibility of buying a moment of pleasure in one of the numerous brothels keep up the miners' spirits. Some are lucky and make a quick fortune, which is usually spent as quickly as it was won. Others never make it and have to attach themselves as day laborers to more successful individuals.

In the town of Cerro Rojo, only gold counts as currency. Everything is valued and measured in gold, including sex—what the miners call *amor minero,* the "gold miner's love." The girls of the local brothels evaluate prospective customers according to the quantity of gold they carry in small containers hanging from their necks. Fights over women and gold are commonplace in the mining town, and guns are always too close at hand when tempers run high and the liquor flows. Crude wooden crosses on the muddy street sides testify to both the miners' violence and their Catholic piety. They are erected to remember the victims of fatal barroom brawls and shoot-outs.

The Traíra valley cuts through a region of rocks and steep hills; the river itself is full of rapids and falls, which make it extremely difficult to travel. Fifteen years ago this was an uninhabited hunting ground, occasionally visited by Indians. The Makuna say that the waters of the Traíra River are poisoned by the ancestral beings, its shores were never meant to be inhabited, and its fish never meant to be caught. There are other such places in Makuna territory—river sections and streams—where fishing is prohibited on religious grounds and which serve as nature preserves of a kind.

The hills near the Traíra River—where miners today extract gold—play an important role in Makuna cosmology. They are the stone pillars at the edge of the world that hold up the sky, the posts of the cosmic long house. They are also looked upon as petrified ancestral beings, mythical heroes that created the world and maintain all life on earth. The gold itself is culturally important to the Makuna. Gold contains the light of the sun and stars, it is the "stars of the earth." Just as the sun and the stars are the visible manifestations of the ancestral beings of the sky world, gold is the sign of ancestral life on earth.

Gold and the light it contains illuminate the Makuna world and allow the shaman to see beyond the appearances of things into the world of spirits. It is called *he cahea makuri,* which can be interpreted as "the vision of the shaman" or "the light of the ancestors." Although younger Makuna will dig gold, the elders say it is sacred; it belongs to the spirits of the hills and should be left where it is. According to the Makuna, the hills at the margin of the world form a protective wall against the forces of evil on the outside. As miners penetrate into their world and take away their gold, the Makuna feel increasingly threatened. The vision of the shaman is blurred, his powers weakened.

For Ignacio and other Makuna elders, gold mining is a sign of an impending catastrophic end of the world reminiscent of its cataclysmic beginning. The cosmogonic myths of the Makuna tell how the present world came into being after the old one was destroyed. Ignacio fears that the present world is now facing imminent destruction and that the new world to emerge from the ruins will have no place for the Makuna.

Although the life style of the mining town draws nearer, traditional rituals remain important to the Makuna. On my return in 1988 I noted the elders' concern and their effort to strengthen Makuna identity. The Spirit Dance, which used to be performed once every two or three years because of the considerable labor required, was performed three times between 1988 and 1990.

At the Spirit Dance, which takes place during the season of the peach palm harvest, people invite animal spirits to dance and drink the juice of the peach palm fruit. It is a feast and ritual exchange: the host group offers the visitors large quantities of peach palm juice, smoked meat and fish, and shaman-blessed coca and snuff. The visitors are the costumed dancers impersonating the animal spirits. The exchange takes place on various levels: food is exchanged between a host group and visitors, but also symbolically between people and animal spirits. People eat the meat and fish, which come from nature, while animal spirits receive the fruits of the peach palm, which are cultivated, harvested, and processed by humans. This exchange expresses the idea that people and animals depend on each other for their survival and reproduction.

When Makuna men go hunting and fishing they also, in their conception, carry out an exchange with the animal world. They believe that in another dimension of reality, all animals are people; they have houses and gardens, musical instruments and ritual ornaments, chants and dances, as people do. They are grouped into communities inhabiting particular territories and also have their headmen, or "masters of the animals." Before major hunting and fishing expeditions—such as those preceding the Spirit Dance—a shaman must visit the long houses of the fish and game animals and negotiate with their headmen. The shaman offers them spirit foods, coca and snuff, and is promised fish and game in exchange.

The relationship between the human and the animal world is comparable to the relationship of reciprocity between different groups of people, particularly groups that intermarry. Marriage among the Makuna ideally involves the direct exchange of women between men; to obtain a wife a man must offer a woman of his own group in exchange. And just as this exchange of women is essential for the reproduction of society, the symbolic exchange with nature through hunting, fishing, and dancing is essential for the continuous fecundity of nature.

The peach palm harvest coincides with the spawning season of the *sabaleta,* the medium-size, fruit-eating fish that is perhaps the most important food fish among the Makuna. At the beginning of the wet season, in March and April, the *sabaleta* migrate from their feeding grounds in smaller tributaries and headwaters to their spawning grounds in the turbid waters and rocky shallows around Manaitara Island on the Apaporis River. The Makuna say that the fish are dancing their Spirit Dance. After spawning, the adult fish head back to their upriver feeding grounds. Many die exhausted on the way, never making it back to the Komenya River. Meanwhile, the eggs apparently float downriver to hatch along the flooded shores of the Apaporis; after two or three years, the young fish ("fish children") begin to migrate upriver to their parents' feeding grounds.

The spawning grounds of the *sabaleta* correspond to the mythical place of

The sabaleta, *below, is the prime food fish of the Makuna. Its seasonal migration to the waters off Manaitara Island, right, also provides the Indians with a pattern for the journey of human souls.*

Makuna origins. The Makuna refer to themselves as the Water People or the Children of the Water Anaconda. According to Makuna mythology, the ancestors of humans, the anacondas, were spirit people who walked across the world from their origin in the east. The trails they left in the soft earth became the rivers, sometimes referred to as the "paths of the ancestors." As they reached the center of the world, the ancestors turned back and swam (or walked) downstream toward their point of origin in the east. On the way they stopped at different points along the rivers and went up on land, thereby turning into human beings. The place where each ancestral anaconda went up on land became the "waking-up-house," or birthplace, of a particular people.

The waking-up-house of the Water People is Manaitara Island. Here, the Makuna say, is the underwater long house of Water Anaconda, their ancestor. In this house live the spirits of deceased Makuna men and women, visible only to the shaman. The spirits of men dance, drink home-brewed beer, chew coca, and take snuff, while the spirits of women cook, laugh, and chat away the evening. The Makuna believe that when a child is born, it receives the soul of a deceased grandparent, which travels from the waking-up-house at Manaitara into this world. The child also receives the name of the presumed soul-giving ancestor. At death, a person's soul returns to its point of origin and joins the spirit people at Manaitara. The Makuna thus believe in a cyclical reincarnation of the soul.

During their migrations, the *sabaleta* replicate the journey of the Makuna soul between the long houses of the living along the Komenya River and the waking-up-house of the dead at Manaitara. This alternating, or cyclical, movement of fish and souls also corresponds to the mythical route of the ancestral anacondas when they traveled from the eastern margin of the world to its center and back again, giving birth to humankind and populating the earth. The Makuna seem to have patterned both the creative journey of the ancestors and the journey of human souls after the seasonal migrations of fish.

In the vision of the shaman, the migrating fish are actually the souls of the deceased and of the generations to come. They are the spirit people inhabiting Water Anaconda's long house at Manaitara. During the Spirit Dance they come to visit the living in their long house, drink peach palm juice and dance, then return to their underwater home. The Makuna say that ritual dancing actually causes the fish to migrate and spawn. By inviting all kinds of animal spirits to drink and dance with them, people make fish and game animals reproduce and multiply in nature. And since fish and game animals in a sense are the unborn future generations of people, ritual dancing also insures the fertility of humankind. Finally, by inviting the spirits of the dead into the house of the living, the Makuna unlock the generative power of death.

Ignacio's face looks serious and somewhat troubled when, toward the end of the Spirit Dance, he sends the fish spirits back to their underwater abode at Manaitara. For him the ritual not only fosters fertility in nature and among people; it is also an effort to infuse new life into ancient lifeways. He hopes to insure the continuing existence of his culture, while not far away, strangers obsessed with finding gold dig away at the foundations of the Makuna world. □

Newton's Second Law of Butterflies

A simple principle of physics governs the evolution of butterflies that can outmaneuver birds

by James H. Marden

In the murky understory of a Central American rain forest, a jacamar sits attentively on a branch overhanging a narrow foot trail, scanning the airspace below for a potential meal. With its jittery energy, iridescent feathers, long, rapierlike beak, and voracious appetite, the jacamar resembles a cross between a hummingbird and a kingfisher. Unaware of the jacamar's presence, a large butterfly floats along the trail; its lazy, undulating flight and flashes of its brilliant metallic blue wings make it a highly visible and an apparently easy catch for the swift and skillful jacamar. As the bird makes its dive and the chase begins, the butterfly shifts to a considerably more erratic and rapid flight. Failing to outdistance the jacamar, the butterfly avoids capture with sudden, unpredictable maneuvers. The chase continues up into the dense vegetation. After a few seconds, the jacamar returns to another perch with an empty beak. On this occasion, the butterfly has escaped.

How did this butterfly, a member of the genus *Morpho,* evade the speedy jacamar? And why did the bird chase it, while ignoring other butterflies that flutter slowly through the forest? The answers are part of a complicated story involving, among other things, the reason that luggage is weighed at airports, Newton's second law of motion, and the gastronomic preferences of birds.

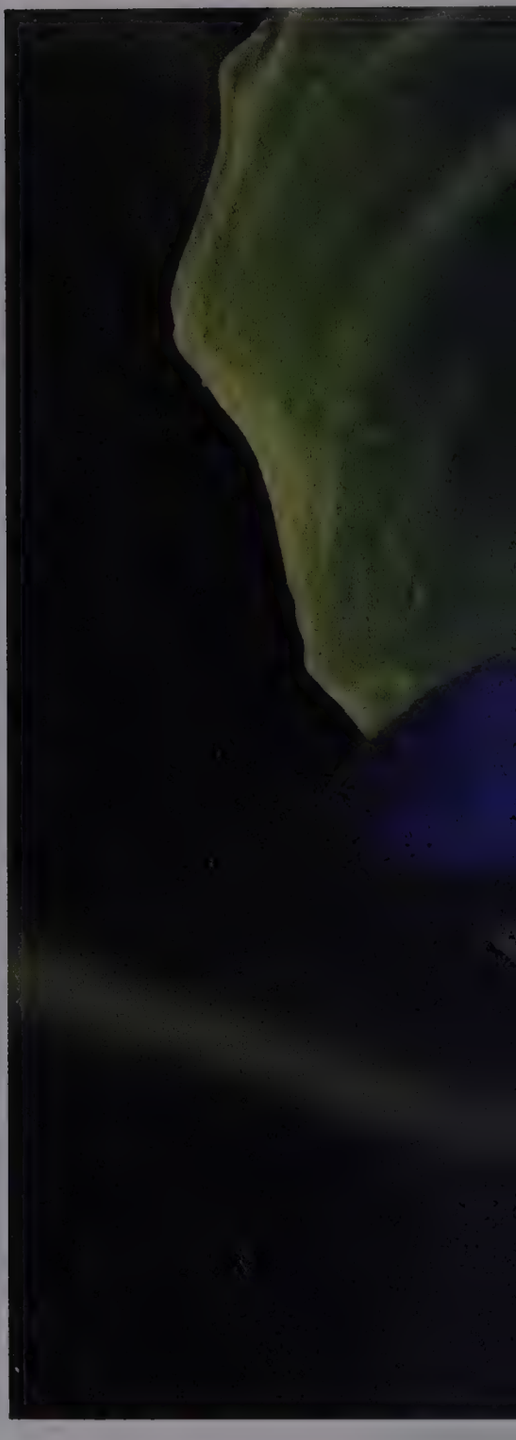
Jacamars are not the only birds with an appetite for flying butterflies. The Neotropics are home to a large number of flycatchers (more than eighty species in Central America alone), motmots, and trogons, many of which make their living by snatching up insects on the wing. This diversity and abundance of flying predators puts intense selection pressure on the butterflies; individuals that are easy prey are quickly weeded out.

One result of natural selection imposed by predators has been the evolution of distasteful—and often toxic—butterflies, which acquire noxious chemicals from plants during their larval stage or as adults. Unpalatable butterflies usually have bright warning colors (known as apo-

A number of Neotropical butterflies, such as this Melinaea ethra lilis, *share color patterns that advertise their unpalatability to birds. With little need for evasive flight, such species can afford to have a heavy abdomen and a relatively small amount of flight muscle.*
Alex Kerstitch

Archaeoprepona demophon centralis, *below, has massive flight muscles in its thorax and a small abdomen, typical of palatable butterflies that can outmaneuver birds. Another palatable species,* Cithaerias menander, *bottom, is a weak flier that never ventures more than a few inches above the forest floor, so that birds cannot dive for it without crashing. It is also protected by transparent wings that mimic those of many unpalatable butterflies.*

James H. Marden



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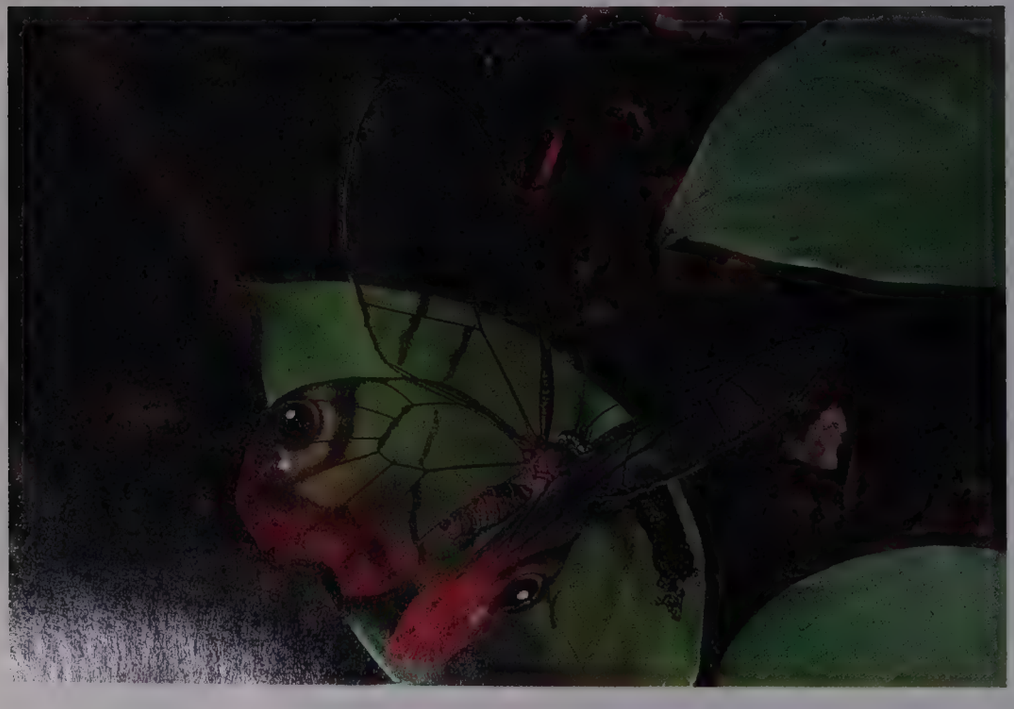


aposematic colors) that birds quickly learn to recognize and avoid. This explains why birds ignore certain butterflies. (The monarch butterfly, which acquires toxins from milkweed as a caterpillar, is a North American example of this phenomenon.)

In any one location in the tropics, dozens of distasteful butterflies and moths share five to ten bright color patterns. Sharing of aposematic color patterns is known as Müllerian mimicry, after the nineteenth-century German naturalist Fritz Müller, who reasoned that if each unpalatable butterfly species had a different pattern, inexperienced birds would need to kill a lot of butterflies before learning to recognize the species they should avoid. Having a shared pattern reduces mortality for all species possessing that pattern.

Other butterflies take advantage of the advertised unpalatability of Müllerian mimics. Certain edible species have evolved to resemble unpalatable groups; they are presumably mistaken for the distasteful species and reap the benefits without having evolved a chemical defense of their own. This phenomenon is known as Batesian mimicry, after the nineteenth-century British naturalist Henry Bates.

This Morpho *butterfly is a moderately evasive flier that shares bright blue colors with many other species that are palatable but difficult for birds to catch.*
Alex Kerstitch

While mimicry has attracted a tremendous amount of attention from biologists for more than a century, few have examined how palatable, nonmimetic butterflies avoid being eaten by birds. Compared with other common insects, butterflies seem to be easy, attractive prey. They lack the nasty sting of bees and wasps, the hard protective shell of beetles, the small size of flies, and the unparalleled maneuverability of dragonflies. The abundance of large, colorful, and apparently defenseless butterflies in environments full of hungry and able predators is indeed remarkable.

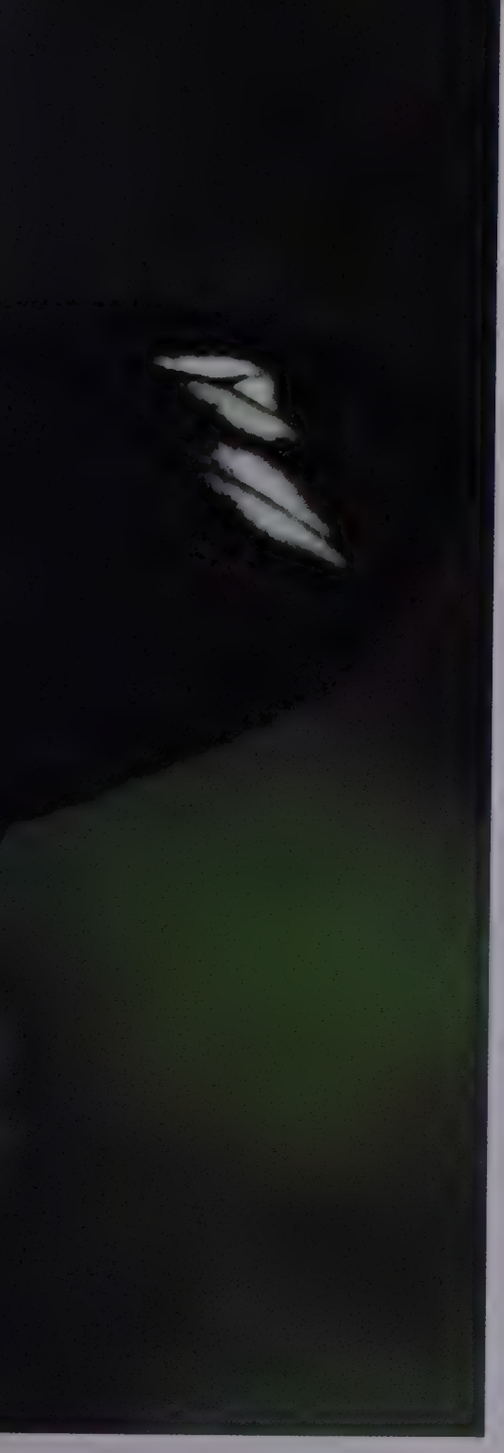
Before I could look further into this mystery, I needed to know which butterflies birds found edible. Studies of palatability had been conducted by offering a variety of butterflies to captive birds and observing how many of each species were eaten. But until recently, only a few species of butterflies had been tested, and only with birds, such as tanagers, jays, and magpies, that do not specialize in catching insects in flight. This gap was bridged in the mid-1980s by Peng Chai, then a graduate student at the University of Texas, who carried out the painstaking task of hand rearing jacamars from the nestling

stage (so that they would have no prior experience to influence their responses) and offering them thousands of live, untethered butterflies (about 2,500 in the final count). Chai performed this study in Costa Rica's remote Corcovado National Park, where he determined the palatability of 140 species of butterflies and diurnal moths. Because of his work, the palatability of a large community of butterflies is now known.

Additional work by Chai and his colleague Robert Srygley showed that the body shapes and flight patterns of palatable and unpalatable species are quite different. These observations supported a hypothesis that I was developing for how palatable species might evade flying predators. From my previous studies of various birds, bats, and insects, I knew that the maximum lift these flying animals can generate depends almost entirely on how much flight muscle they possess. This relation varies remarkably little (from 60 to 80 newtons of lift per kilogram of flight muscle) and is not affected by the size or shape of the wings or by the size of the animal. If all animals generate about the same amount of lift for a given amount of muscle, might some butterflies with a high proportion of flight muscle to total body mass be better equipped than others to evade airborne predators? This would explain Chai and Srygley's observation of stout body shapes and more erratic flight patterns of palatable species.

In 1988 and early 1989, I visited Corcovado National Park to test my hypothesis on the same butterfly community that Chai had worked on. The field station was modest, lacking electricity, hot water, screens, or other creature comforts. Fortunately, my experiment was about as low-tech as things get these days; I needed only to dissect a male and female butterfly of each species and weigh their body parts with a small electronic balance powered by a car battery (which I occasionally recharged with a portable generator). Most of my time was spent wandering through the forest with a net or checking traps (net cages baited with rotting fruit) in search of the widest possible selection of butterflies and day-flying moths. After four months of collecting and dissecting, I had assembled data on 124 species.

These data showed that, indeed, palatable and unpalatable species differ greatly in the way they allocate body mass. Among nonmimetic palatable species, which should have the greatest need for evasive flight, the average amount of body mass invested in flight muscle is 35 percent in females and 41 percent in males. Respective figures for unpalatable Müllerian mimics, which should have the least



Heliconius doris, *left, collects nectar from* Lantana *blossoms. It has a large, heavy abdomen and a small thorax, but because it shares the warning colors of several other species of unpalatable butterflies, it has little need for evasive flight.* Anartia fatima, *below, is a poor flier and often becomes lunch for birds such as this blue-crowned motmot.*

Kevin Schafer/Martha Hill

need for evasive flight, are 22 percent and 28 percent. Intermediate in their need for predator evasion should be Batesian mimics and nonmimetic unpalatables, for they possess either visual or chemical protection, but not both. As I predicted, these species have intermediate investments in flight muscle: 26 percent and 36 percent in Batesian mimics and 33 percent and 38 percent in nonmimetic unpalatables. This dependence of body design on mimicry and palatability is consistent across diverse taxonomic groups, including a number of day-flying moths.

How does the large investment in flight muscle by the palatable butterflies affect their flight performance and ability to evade capture by birds? Flight performance is a vague term, since there are many aspects of performance, not all of which depend on power. For example, when birds swoop down from their perches, their velocities are greater than any speeds butterflies can achieve. But if a butterfly sidesteps a bird's initial dive, the bird must slow down and change direction. At this point, bird and butterfly have low velocities and must work against gravity. The ability to accelerate is at a premium, especially since the erratic flight pattern of butterflies dictates that a pursuing bird must frequently change direction to keep pace.

Filming birds in pursuit of their insect prey would have given me a chance to analyze the aerial combat in slow motion, but when and where these encounters took place was too unpredictable. Instead, I used simple physics to estimate how quickly the birds and butterflies could accelerate. According to Newton's second law of motion, acceleration is equal to force divided by mass. I found that the force, or maximum lift, produced by butterflies is about 72 newtons per kilogram of flight muscle. Multiplying this figure by the amount of flight muscle and dividing by total body mass yields a butterfly's maximum acceleration. For birds, the calculations were the same except that their maximum lift equals about 62 newtons per kilogram of flight muscle. (I was spared the task of measuring the body and flight muscle masses of thirty species of Neotropical aerial insectivores because the figures had already been published in the literature.) When I compared results, I found that more than 95 percent of palatable butterflies and day-flying moths could accelerate faster than the birds with the highest acceleration. In contrast, only 30 percent of unpalatable species could accelerate at a higher rate than the birds. At the low end of the spectrum, some Müllerian mimics have so little flight muscle that they can just barely counteract gravity and are probably incapable of any evasive maneuver other than a dive.

Although unpalatable butterflies and moths, particularly Müllerian mimics, are poor fliers compared with more tasty species, they benefit by being able to invest more of their body mass in tissue other than flight muscle. Unpalatable females have larger ovaries, which may allow them to produce more offspring, and males have larger guts, which may confer an enhanced ability to digest food. Predation and the basic physics of flight, therefore, help determine how a butterfly's body mass is allocated to different tissues and capabilities.

Anyone who has had his or her luggage weighed before boarding an airplane has encountered a human application of the physics of weight versus performance; an overloaded plane will not have sufficient lift to take off. Designers of military air-

A day-flying moth, Urania fulgens, *below, is unpalatable but does not resemble other distasteful species. Perhaps because of frequent attacks by birds that do not recognize it, the moth has more flight muscle than species that share warning colors.* Philaethria dido, *right, is a palatable species and an evasive flier that is mimicked by a weak-flying species.*

Photographs by James H. Marden

craft are especially familiar with this problem. Fighter jets that engage in aerial combat carry minimal fuel and armaments; they cannot afford the excess weight if they are to outmaneuver enemy jets. Other aircraft carry tremendous loads of fuel, armaments, personnel, and equipment, but these jets are sitting ducks for enemy fighters. An aircraft can be either evasive or capable of carrying large loads, but it cannot be both. For butterflies, these alternatives are manifested in the way body mass is allocated between flight muscle and abdominal contents such as guts and ovaries.

As I became familiar with the Costa Rican butterfly community, I noticed that unpalatable species are not the only ones that share bright patterns. One group of palatable butterflies shares iridescent blue and black upper wings. The species of another group, which includes a day-flying moth, have brown-and-white wings, and two species have green and black stripes. Within each group, the patterns are so similar that I had difficulty distinguishing them in the field without some practice. Why should palatable species, some of which are only distantly related, evolve to share color patterns? What possible advantage is there in advertising one's edibility to a predator?

Once I compared the acceleration rates of butterflies and birds, the answers became clear. Among the palatable species, some butterflies that are adept at evasive maneuvers have evolved similar color patterns. The process is presumably like that producing Müllerian mimics among the unpalatable species, except that in this case, the colors carry the message, "you cannot catch me, so don't bother trying," rather than, "I taste bad." Birds may learn to recognize species they are not likely to capture so that they can avoid wasting time and energy chasing them.

Not all the palatable butterflies that share these warning colors are capable of tremendous acceleration, however. Some underpowered species may be analogous to Batesian mimics. Although less able fliers, and therefore easier prey for birds, they may benefit from any resemblance to highly evasive species and may have gradually evolved to look more like them.

While I was in Costa Rica conducting this research, my wife, Paula, sent me a Gary Larson cartoon showing a young man admiring his "wingless butterfly collection." Larson leaves us wondering what kind of warped person would collect butterflies, snip off their wings, and mount the bodies on pins. But my work demonstrates that by looking beyond the colorful wings, one can learn much from the butterfly's body. □

Northern Exposure

There'll be a hot time in the old town tonight

by Roger L. Welsch

I don't remember in which class it happened, but I do remember I saw this question somewhere on an exam in high school. Human beings die for sure when the temperature reaches: (*a*) 98.6° Fahrenheit, (*b*) 120° Fahrenheit, (*c*) 150° Fahrenheit, (*d*) 100° Celsius.

I wasn't exactly a whiz-kid in high school, but I knew all about 98.6 from a popular song of the time. I cannot imagine why, but I also knew that the record high temperature for North Dakota was 122° F (in July 1936, almost exactly six months after that state's record low of −60° F). A lot of folks were still alive in North Dakota, especially in Bismarck, so I crossed out option B. We don't have Celsius degrees in America, so option D wasn't the right answer. Leaving only answer C.

Later in life, after some travel in this world, I learned three things about the Celsius scale: 0° C is freezing, 30° C is very pleasant, and 100° C is boiling. I realized the response they were looking for was D. Considering that in high school I usually didn't get the questions right, there wasn't much sense in brooding about one wrong answer. But that's not the point.

The point is the astonishment I felt when I leaned forward in a Helsinki hotel sauna and looked at the thermometer, which read 103° C.

I sat back down on the smoking redwood bench, resumed breathing through my hands to keep from broiling my lungs, took a quick look at the little blisters on my hands where I had leaned against nail heads in the wall while looking at the thermometer, and remembered that question on the high school exam. Surely, surely, the human body cannot endure temperatures over boiling. I could see the headline: "American Folklorist Suffers Serious Burns in Helsinki Sauna."

I started to reach toward the bottle of beer I had brought into the sauna moments before and a friend slapped my hand away. "Big mistake," he said. I looked at him with astonishment and, probably, indignation. He smiled, took another breath through his hands, and gasped, "That bottle is already so hot that if you touch it, you'll burn yourself." I tapped the bottle with my finger tips and could feel that it was indeed beyond handling. I saw the headline: "Promising American Folklorist Dies Tragically in Sauna Far from Home."

The occasion was peculiar anyway. I was attending an international conference, twenty years ago by now. During the day, delegates from all over the world sat around in suits and ties calling one another "Herr Doktor Professor This" and "the Distinguished Delegate from the United Kingdom That" and reading formal papers and making scholarly statements, laughing only now and then at incredibly sophisticated bons mots. Then, at the end of the day, we took off all our clothes and sat together in a sauna.

They do that in Finland and, for that matter, a good part of the rest of Scandinavia. There is a sauna for every three people in Finland, and that's the way it's been for 2,000 years. I once visited a banker's office in Finland; he has a sauna adjoining his office so that when he concludes a loan, issues a certificate of deposit, or bounces a check, he and his clients can tear off their clothes, turn up the heat, and sit buck naked, sweating like mules at harvest and hitting themselves with birch switches. No kidding. Hitting themselves with sticks!

But don't let all this talk about naked bodies give you the wrong impression. Everything I have read or experienced counsels a rigid primness with regard to the Scandinavian sauna bath. As a Norwegian truck driver roughly the size of his truck told me just before a sauna riot on board a ship in the North Atlantic, "De sowna bat is vere bapies is borned, by Gott."

That was the first time I was in a sauna, on a ferry running between Newcastle and Oslo—on my way to that academic meeting in Helsinki. The ship was carrying a lot of Scandinavian trucks, which meant that it was also carrying a lot of Scandinavian truck drivers. And Scandinavian truck drivers love their saunas. By the time I got to the ship's sauna, there were already five blond giants sitting there, hulking and sweating. And then laughing as they watched me struggle with the idea of relaxing with a bunch of naked men in a room heated to the temperature of the surface of the sun.

I struck up a conversation with one of the drivers, a Norwegian. (Actually, he broke the ice—that's a laugh—by telling me that if I grabbed one of the little boards hanging on the hook outside the sauna door, I could sit on it and not blister my butt. It was too late but I appreciated his thoughtfulness.) He explained the use of the birch switches to me: one holds them across the knees and under the arms so they are roughly at body temperature. When you beat your broiling body with them, it feels cool, sort of. ("But if you wanted to feel cool, wouldn't it be a good idea not to go into the sauna in the first place?" I asked. The Norwegian truck driver thought that was a hilarious proposition, not going into a sauna.)

He showed me how to step out of the sauna and plunge unrestrained into the ice-cold shower. My pores slammed shut so loudly, passengers heard it three decks above. In 3.2 nanoseconds my pulse went from pinging like a Chevy van on cheap gas to thudding like a timpani during a dirge.

"This cannot possibly be good for your heart," I groaned.

"Oh ya sure," my new friend said seriously. "If you haf a bad heart, she shows up early."

Oh boy: "Young, Promising American Scholar in Otherwise Good Health Suffers Temperature Fractures and Shatters Aboard Norwegian Death Ship!"

We went back into the sauna and five more blond hulks came in behind us. The

conversation quieted. I sensed tension. One of the newcomers had two bottles of beer. My Norwegian friend gnarred. (That's the only word for what he did. He gnarred.) The newcomer took the beer and poured it on the rocks of the sauna oven. The room filled with beer steam and a smell like baking bread. My Norwegian truck-driver friend turned to me and said loudly enough for all to hear, "Damt Svedes! Dem uncifiliced barbarians act like dey don't know dat de sowna bat is vere bapies is borned, by Gott. Damt Svedes!" Pretty soon everyone was gnarring.

"Attractive, Dynamic, Young, Promising American Scholar Killed by Heat-crazed Truckers in Sauna Riot Aboard Norwegian Hell Ship!"

Which is to say, some Scandinavians take their saunas seriously. The sauna is indeed the place where babies are born and where new mothers recover. I suspect the sauna bath has been the cleanest, most sterile room on Scandinavian farmsteads since the Iron Age.

A publication distributed by the Finnish embassy says, "For a Finn the sauna is sacrosanct. From olden times children were taught to behave in the sauna as if in a church. Sexuality, noisiness, and otherwise indecent behaviour never had a place in the sauna. Ostentatious decoration of [a sauna] is out of the question."

So why am I telling you all this? Because I fell in love with the feeling of the sauna bath and have wanted one for the twenty years since those days on the ferry ship and at the Helsinki hotel, that's why. This past summer, to convince my wife, Lovely Linda, that I needed a sauna more than the house needed a paint job, I showed her some brochures from sauna companies. Every one of them showed naked blond beauties and in some cases naked couples grinning in such a way that there wasn't much doubt about what they were up to. Not that Lovely Linda doesn't grin that way now and then herself, but she wasn't crazy about naked blondes grinning like that in our sauna, she being Czech and all. So I showed her the serious stuff from the Finnish embassy.

"Good grief," I explained, "when I was dating, I worried about sweat on my upper lip. Do you have any idea what sweat is on when you're in a sauna? Despite the rumors and the brochure pictures, no one has so much as kissed in a sauna."

Linda wasn't the only skeptic. We live in a small Nebraska town where saunas are not *de rigueur,* so I had a lot of explaining to do around town. Village elders Gaylord Obermiller, Chancey Stewart, and Swede Peterson came by one day to look over our addition and asked about the little redwood room with the big heater.

"Sauna bath," I explained. "It's where you go to sweat."

"Uh-huh," they said. "Why would you want to do that?"

"Feels good," I explained.

"Uh-huh," they said.

I explained that the sweat bath is not only popular in northern Europe but that the Indians of North America used the sweat lodge throughout their history and, for that matter, some still do.

"Uh-huh."

I explained that water is thrown onto the hot rocks to make the room feel even hotter, and I told them about the cold showers and showed that I had even placed a door near the sauna exit so we can jump out and roll in the snow in the winter.

"Uh-huh."

And we are planning to get a treadmill and exercise bicycle, so we can walk and pedal without going anywhere. Maybe even some other devices that will let us work without getting anything done. And an air conditioner so we can use the exercise equipment even during the summer. And then we'll go relax in the sauna.

"Uh-huh."

Folklorist Roger L. Welsch lives in Dannebrog, Nebraska.

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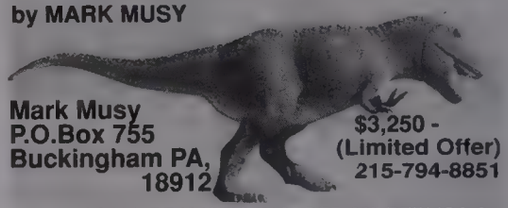

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Winter's Star Attractions

by Gail S. Cleere

In Mark Twain's *The Adventures of Huckleberry Finn,* Huck floats down the Mississippi River on a raft with his companion, Jim, and ponders the heavens. He says, "We had the sky up there, all speckled with stars, and we used to lay on our backs and look up at them, and discuss about whether they was made, or only just happened." Unless you are with someone who can point out the constellations and liven them up with tales of their mythological origins, the night sky does seem to be "all speckled with stars," and learning it can be difficult. But January is one of the best months to get started: more first-magnitude or brighter stars appear in the winter than during any other season. In the evening, constellations appear that are easily visible even in city skies.

Start by looking toward the southeast for the most prominent constellation in the sky. This is Orion the Hunter, with three stars forming a belt about his waist. The four bright stars tracing his arms and legs include two first-magnitude stars, Betelgeuse, an orange-red giant star at upper left, and Rigel, a blue giant at the lower right. According to Greek mythology, Orion was a hunter-warrior who grew to such an enormous size that he could walk on the ocean floor without getting his head wet. Other cultures have associated the constellation with heroes, warriors, and kings (the French even tried to rename it Napoleon). The giant had two hunting dogs, Canis Major and Canis Minor. Look east (left) of Orion and down to the brightest star in the sky, Sirius, the Dog Star, in the constellation Canis Major. Above and left of Sirius is another bright star, Procyon, which is in Canis Minor.

Look above and right of Orion to the northwest to find Taurus the Bull, whose head is marked by a V-shaped group of stars lying on its side, known as the Hyades cluster. (Although the bright orange Aldebaran appears to be the prominent star in that group, it is actually much closer to us than the Hyades.) In ancient Arabia, the fainter stars in the Hyades were known as the Little Camels, which the suitor Aldebaran drove across the sky to impress the Pleiades, who had previously spurned him on account of his poverty. The Pleiades is a group of seven stars located northwest of the Hyades.

Just northeast of Orion is the constellation Gemini, with its bright twin stars, Castor and Pollux. Although called twins, in the Greek myth the boys were borne by the Spartan queen Leda but had different fathers, one mortal and one divine.

For those readers just becoming acquainted with the night sky, I recommend David Chandler's Night Sky Planisphere, a device that gives you a current picture of the sky once you dial in the date and time.

The Planets in January

Mercury rises about an hour before sunrise at midmonth but remains too low on the horizon to be easily seen.

Venus rises about two hours before the sun at midmonth and can be seen in the southeast by sunrise. This month the planet shines like a beacon at −3.5 magnitude, considerably brighter than any star.

Mars, too, is a morning "star" this month, but it rises near the sun and will not be easily found. In the morning twilight, look carefully along the southeast horizon for a dull, reddish object. On the morning of the 11th, Mercury and Mars will be very close to each other, the latter being dimmer.

Jupiter is a magnificent evening and early morning object, rising about 9:00 P.M. in the constellation Leo.

Saturn is up during the daylight hours and sets with the sun, lost in the solar glare. Saturn is in conjunction with the sun (directly behind it) on the 29th.

The **Moon** is new on the 4th at 6:10 P.M., EST; reaches first quarter on the 12th at 9:32 P.M., EST; is full on the 19th at 4:28 P.M., EST, and reaches last quarter at 10:27 A.M., EST. This month's new moon brings an annular solar eclipse, in which the moon does not completely cover the disk of the sun, leaving a ring of light around the moon's edge. Observers in western North America will see a partial eclipse beginning late in the afternoon and continuing through sunset, while observers in the Los Angeles–San Diego area will see the annular eclipse as the sun sets over the Pacific Ocean.

The Quadrantids, one of the best meteor showers of the year, is on the night of the 3rd/4th. The shower, which may reach rates of 110 meteors per hour, peaks at the time of the new moon, so the sky will be dark. The meteors appear to originate from the north, near the constellation Draco. The name of the shower, however, comes from Quadrans Muralis, or mural (wall) quadrant, a constellation that is no longer recognized.

Quadrans Muralis was named during the eighteenth century when a number of faint constellations were designated to fill in gaps among the classical constellations and, in some cases, to curry favor with royalty. (Edmund Halley, for instance, named a constellation in the Southern Hemisphere Robur Carolinum, for the oak tree in which King Charles II hid following his defeat by Cromwell in 1651. For this, the king granted Halley a master's degree from Oxford.) The changing names of some of the stars and constellations muddled things so badly that no two celestial maps were in agreement. About the turn of this century, British astronomer Agnes Mary Clerke complained that "a star has often as many aliases as an accomplished swindler." In the 1930s, the International Astronomical Union finally settled things by firmly fixing all the constellation names—the ones used today.

Gail S. Cleere writes on popular astronomy and is a founding member of the International Dark Sky Association, an organization dedicated to preserving the skies for astronomy.

Keeping It Simple

by Malcolm S. Longair

One of the more remarkable and encouraging developments in contemporary science over the last ten years has been the proliferation of books that attempt to explain recent developments to the layperson. There is, of course, nothing new in the idea of popularizing science, one of my favorite references being Francesco Algarotti's 1737 book entitled *Newtonianismo per le Dame* (Newtonianism for Ladies), written within fifty years of the publication of Newton's *Philosophiae Naturalis Principia Mathematica*. Of course, everything is relative. Algarotti and his successors had the problem of explaining classical physics to a lay audience. The speed with which scientific discoveries can be communicated to the public is well illustrated by the rapidity with which Crookes tubes became popular toys in the late nineteenth century and X-rays became a tool of the medical profession within a year or so of their discovery by Röntgen.

The problem for the contemporary writer is that with the development of relativity and quantum mechanics, let alone the amazing new concepts in particle physics, the task is vastly more difficult. Pictures involving common sense and ordinary intuition come badly unstuck, and one has to throw away a number of preconceived notions to come to terms with how matter actually behaves.

The challenge has been addressed by a number of excellent books, including Steven Weinberg's *The First Three Minutes*, James Gleick's *Chaos*, and Roger Penrose's *The Emperor's New Mind*. Most spectacular of all, Stephen Hawking's *A Brief History of Time* has already achieved cult status. Rumor has it that *A Brief History* may be one of the most widely bought but least read books, but the ordinary person's desire to have some appreciation of Stephen Hawking's vision of the state of cosmology and physics represents a major advance.

I have in front of me three new books that set out to enlighten the layperson about modern physics and cosmology. The differences in approach are striking and reflect three different ways of expounding the material to the public. David Ruelle's book, *Chance and Chaos*, by one of the founders of the rapidly developing field of nonlinear dynamics and chaos, provides a highly personal view of this subject and many others. This is one man's individual approach to the great advances of theoretical physics and how he would explain them to the nonspecialist. Alan Lightman's book, *Ancient Light: Our Changing View of the Universe*, is a careful and readable account of contemporary cosmology, including character sketches of some of the major players in the field. The third, *The Matter Myth*, by Paul Davies and John Gribbin, is by far the most ambitious; it attempts to explain essentially everything in modern particle physics, chaos, and cosmology within what the authors call a new paradigm for modern physics.

CHANCE AND CHAOS, by David Ruelle. *Princeton University Press, $24.95; 190 pp., illus.* ANCIENT LIGHT: OUR CHANGING VIEW OF THE UNIVERSE, by Alan Lightman. *Harvard University Press, $18.95; 170 pp., illus.* THE MATTER MYTH: DRAMATIC DISCOVERIES THAT CHALLENGE OUR UNDERSTANDING OF PHYSICAL REALITY, by Paul Davies and John Gribbin. *A Touch Stone Book/Simon and Schuster, $25.00; 307 pp., illus.*

The three books elicit quite different responses. One of the key points about understanding physics, which I emphasize to all my students, is that there is no single way to understand the subject. All physicists build up their own personal pictures of how the subject hangs together, how to look at particular problems in physics, and how best to explain them to others. If this were not so, there would be only one book on physics, and the subject would not require the tremendous feats of imagination to solve what seem, at first, to be intractable problems. Thus, I always enjoy books that set out one author's view of how everything hangs together. Ruelle's book is a wonderful example of this approach. He is unabashed about advancing his personal prejudices as a mathematician but, in the process, conveys much of his individual creativity as a scientist. The book's chapters are no more than four to six pages long, but each is carefully honed to make simple but profound points. With remarkable economy, Ruelle encompasses such diverse areas as chaos, turbulence, quanta, entropy, statistical mechanics, complexity, and Godel's theorem, as well as diversions into economics, intelligence, and the meaning of sex. The book is a tour de force. Written very subjectively, it may not appeal to everyone, but it would not be as stimulating and thought-provoking if it were less individualistic.

Lightman's book is a short and simple introduction to modern cosmology, with a strong emphasis upon observation and its interaction with theory. It has plainly benefited from his previous volume *Origins*, in which a number of leading cosmologists were interviewed and their thoughts set down. One way of looking at this book is as a background primer against which the interviews in *Origins* should be judged. Its merits are that it is accurate and does not go further than current observations warrant. The real strength of the book, however, is that it gives proper attention to the observations. Thus, Lightman's book can be recommended as a quick, reliable guide to the current status of observational cosmology. Where the book comes unstuck, as most books do, is in coming to

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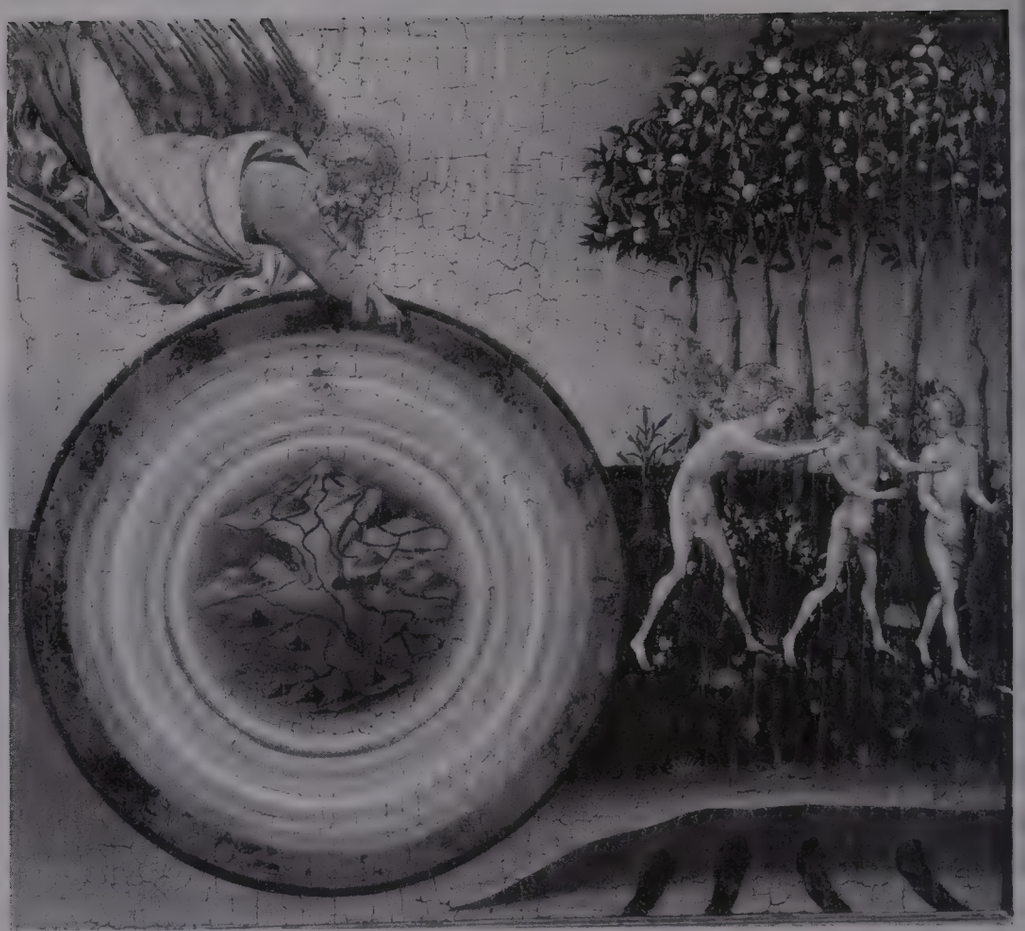

Expulsion of Adam and Eve from Paradise, *by Giovanni di Paolo, from* Ancient Light: Our Changing View of the Universe
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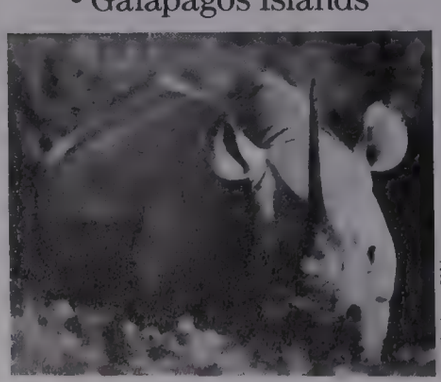

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terms with what may have happened in the very early universe. This forms a relatively small part of the book, however, and the reader must look elsewhere to find these ideas discussed in more detail.

One of the places the reader might look is in *The Matter Myth*. Both authors are prolific writers and popularizers of science, and I applaud their continued efforts. I have, however, some concern about their latest venture. The book sets out to be all encompassing and makes strenuous efforts to explain even the most difficult pieces of current speculation by everyday analogies. The authors claim that they can adopt an all-embracing (or "holistic") view because of what they term a "paradigm-shift" in the way that physicists think about physical problems nowadays. The claim is that deeper understanding of relativity, quantum mechanics, and statistical mechanics, as well as of chaos, leads to a completely new, nondeterministic view of science. They hold that the deterministic Newtonian view has been superseded by these new ideas.

I believe this is somewhat of an exaggeration. I know of no practicing scientist who has been unaware, since school or university days, of the intrinsic uncertainties and statistical probabilities that determine the way matter behaves (encapsulated in James Clerk Maxwell's insight of 1867 of the statistical nature of the laws of thermodynamics, and Heisenberg's uncertainty principle of 1927). Indeed, it would be a worthless physics course that did not impress upon students the intrinsic unpredictability of physical systems.

To this rich mixture have been added remarkable advances in understanding nonlinear dynamics and the ease with which Newton's laws of motion can provide nondeterministic behavior. All practicing scientists have been living comfortably with these intrinsic indeterminacies in the laws of nature and have taken on board the new developments as further tools of the trade. My own belief is that scientists are pragmatic when it comes to tackling physical problems. They are far too busy trying to solve specific physical problems using whatever tools are available to wonder if they have shifted paradigms or not.

I believe it is much safer to treat the book as an explanation of contemporary ideas in physics for laypeople without the paradigmatic overlayer. There is one particularly interesting chapter in which Paul Davies describes the problems he had in understanding general relativity. This is a very honest account and is worth reading

to get a flavor of the struggles professional scientists have to go through to understand their subject. At the end, Davies writes, "Today, I have grown used to dealing with the weird and wonderful world of relativity. . . . Yet, in truth, I have come to terms with these ideas more through the familiarity of repeated use than through the acquisition of an esoteric power of intuition. I believe the reality exposed by modern physics is fundamentally alien to the human mind, and defies all power of direct visualisation."

It is this challenge that leads to the many analogies and metaphors used throughout the book to attempt to explain the phenomena of modern physics. In my view, the way to explain many of these apparently difficult ideas is to remind the reader constantly that all the really substantial bits of the story are firmly based upon outstanding experimental and observational data. Despite Davies' inability to visualize what is happening in some cases, many of the most difficult bits are completely substantiated by laboratory experiment. It is reassuring to remember that matter would behave in these peculiar ways even if we didn't have the mathematics to describe it.

A further concern is that without very careful reading of the book, the nonexpert cannot disentangle the really substantive facts from the speculations. For example, the authors treat the inflationary model of the early universe as a fact. In reality, it is one possible solution to a number of well-defined physical problems, but it relies upon wholly untested physics. There is a perfectly acceptable version of the inflationary model that involves no physics at all but that illustrates how the concept can help with some of the problems. I believe the authors should warn the reader that (*a*) there is not yet a physical realization of the forces that could cause the inflation, and (*b*) we have no way yet of testing experimentally whether or not the ideas are correct. To compound the problem, the particle physicists argue that the only place to test the theories is in the very early universe itself.

In the same vein, Davies and Gribbin talk of axions, gravitinos, photinos, and wormholes in space-time, as if these really exist. While the professional can take a suitably dispassionate view as to how seriously these should be taken, it is impossible for the lay reader to make these judgments. Despite these concerns, Davies and Gribbin's valiant effort makes some of the more remarkable developments and theoretical speculations plausible. The best way to read the book is to regard it as a vade mecum for the types of theoretical speculation that have considerable common currency. Ideally, it should be contrasted with the more sober reality of astrophysical cosmology presented by Lightman.

The most important point about these modern developments is that all the great problems come out of well-defined physical phenomena, supported by high-quality experiments and observations. The theoretical side of the story has now had more than its share of brilliant exponents. What we need are equally brilliant writers who place the whole subject in its experimental and observational context. The amazing achievements of modern science are as much triumphs of experimental genius as of theoretical physics.

Malcolm S. Longair is Jacksonian Professor of Natural Philosophy at the Cavendish Laboratory, University of Cambridge. He was formerly director of the Royal Observatory, Edinburgh, and Astronomer Royal for Scotland. His most recent book is The Origins of Our Universe: The Royal Institution Christmas Lectures.

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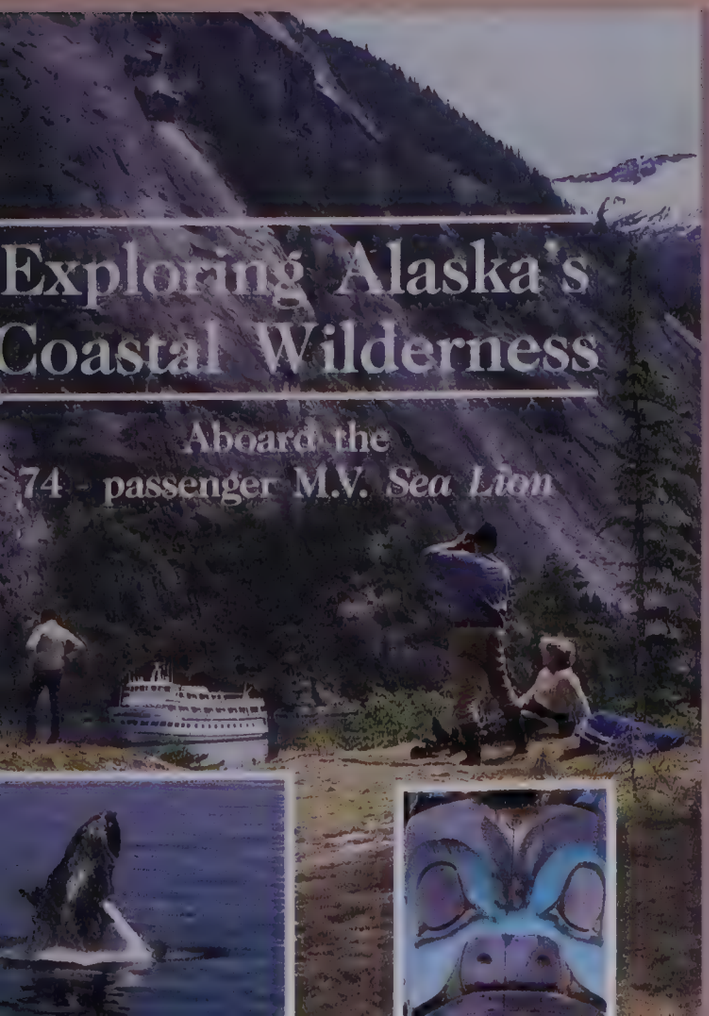

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MacMillan Park, British Columbia

by Robert H. Mohlenbrock

Extending from California to Alaska, the old-growth coniferous forests of northwestern North America with their gargantuan trees provide a parklike habitat for many species of plants and animals. Thousands of acres of these forests have been destroyed during this century, and many more are threatened and the subject of heated controversy. One 332-acre forest that still stands is MacMillan Park on Vancouver Island, managed by the British Columbia Ministry of Parks. Its preservation in the midst of massive lumbering was made possible in the 1940s when forester and philanthropist H. R. MacMillan, recognizing the value of, and easy access to, this old-growth forest, decided to ban tree cutting from the area and donate the land for a provincial park.

MacMillan Park lies secluded in a somewhat flat-bottomed valley surrounded by conifer-clad mountains. Carved by ancient glaciers, the valley continues to be shaped by the erosive action of the Cameron River, which flows north into finger-shaped Cameron Lake. After eons of depositing materials, the river has left a series of terraces whose composition of sand, clay, and loam are ideal for the development of massive trees.

The striking feature of MacMillan Park is the concentration of giant Douglas firs, western hemlocks, western red cedars, and grand firs, all draped with wispy, moisture-laden mosses. The size and longevity of these conifers, or cone-bearing trees, is primarily a result of the climate—not so much the total precipitation and average temperature, but the pattern of these factors during the year. Winters are wet and not too cold, paving the way for vigorous growth in the spring. Rainfall is limited during the summer (the driest month receives less than an inch and a half of rain), but the temperature rarely exceeds 70° F. These conditions sustain a steady, prolonged growth pattern.

The most numerous and tallest trees in the forest are Douglas firs, which grow more than 200 feet high where the soils are moist and very rich in nutrients. A few of the oldest Douglas firs are estimated to be about 800 years old, but most decline after 300 or 400 years, as fungal rots attack their roots and bases. They owe their longevity to their thick bark, which insulates them from fires that can destroy the other conifers. Dead giants frequently remain standing, disintegrating from their tops down, a pattern often observed in primeval forests. Young Douglas firs do not do well in the shade of the dense canopy but can gain a foothold in forest openings or in adjacent, slightly drier habitats with adequate sunlight.

Although they do not usually grow quite as tall as the Douglas firs, western hemlocks thrive in the shade cast by the taller trees and in the acidic soil created by the decaying wood of conifers. The hemlocks serve as hosts for dwarf mistletoe, a plant that lives on the tree branches and obtains nutrients from them. Although the mistletoe does not generally kill its hosts, it certainly reduces their vigor.

In seepage areas along the Cameron River and its tributaries, where the soil is extremely rich in nitrogen, western red cedars grow to their maximum size. Botanist V. J. Krajina has shown that under favorable conditions they may reach 180 feet in a hundred years. The trees are well

In winter, ice crystals border a leaf, above; snow on Douglas firs, facing page, will spur vigorous spring growth.

Photographs by Steven C. Wilson; Entheos

Steven C. Wilson: Entheos

Bubbles collect under ice at the edge of Cameron Lake, left. Cameron River, below, is shallow by summer's end.
Neil McDaniel

adapted to poorly drained soils where water may stand periodically. The grand fir also grows where there is seepage, but it does not tolerate standing water.

In addition to the evergreen conifers, two deciduous trees, broadleaf maple and red alder, are important components of the forest. The maples grow best where the soil is moist and rich in nutrients, but they can also colonize drier areas opened up by the demise of one or more canopy trees. After fifty to eighty years, the broadleaf maples are overtaken by the conifers that have grown in their shade.

Red alders tolerate a variety of soil conditions but seem to do best in the floodplain adjacent to streams. Their root nodules contain nitrogen-fixing bacteria that enrich the soil. Like the broadleaf maples, red alders can pioneer newly available areas but eventually give way to conifers as the forest matures.

Forester Alexander Inselberg and his colleagues have made a thorough study of MacMillan Park and identified several vegetation communities. In nearly 40 per-

MacMillan Park

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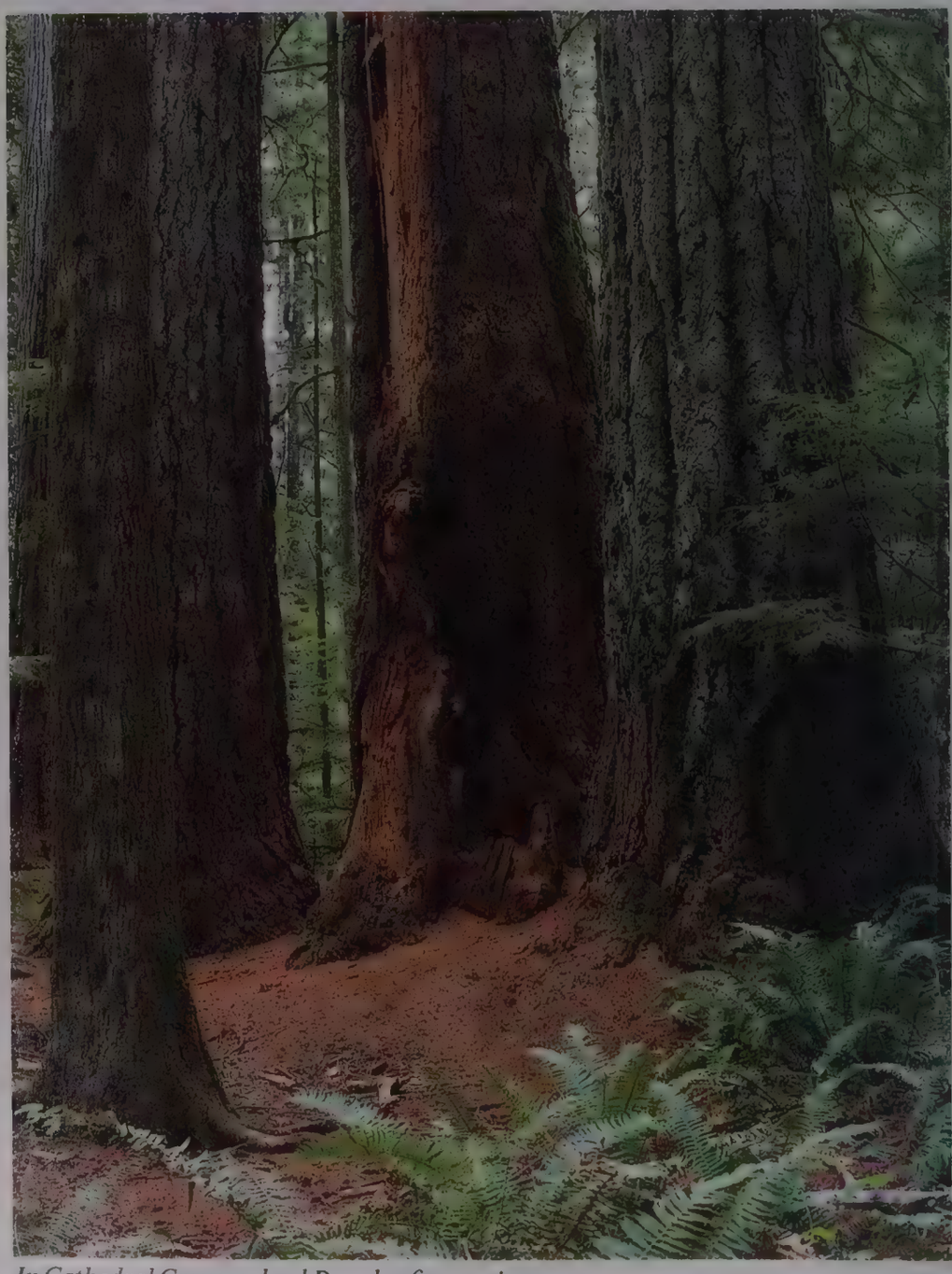
Joe LeMonnier

cent of the park, Douglas fir, western hemlock, and western red cedar dominate the canopy while vanilla leaf and sword fern prevail on the forest floor. The understory also includes foamflower, ovate-leaved trillium, twisted-stalk, twayblade orchid, and various shrubs—western yew, red huckleberry, Oregon grape, devils-club, and salal. This community forms the heart of MacMillan Park, including the section known as Cathedral Grove, where the largest trees may be seen. Because of the thick understory, traversing this forest is not only difficult but also damaging to the plants; visitors should keep to the trail.

Three important wetland communities are found near Cameron Lake. In shallow depressions, old floodplain channels, and protected inlets along the lake, where a slow but steady supply of water keeps the soil saturated throughout the year, western red cedars tower over dense colonies of lady fern and skunk cabbage, two species that thrive under very moist conditions. In finely textured soil that has been deposited along the mouth of the Cameron River, patches of skunk cabbage grow beneath dense thickets of red-osier dogwoods. And a swampy habitat prevails in low depressions, where silty soil is often submerged beneath water during the winter rainy season. Dense colonies of meadow horsetail and slough sedge grow here, interspersed with clusters of low-growing woody species—Sitka willows, Pacific willows, and red alder saplings.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.



In Cathedral Grove, a dead Douglas fir remains standing amid its giant neighbors.
Ernest Cooper

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At the American Museum

Japan Month

Issues facing contemporary Japan will be discussed in a series of Saturday evening lectures cosponsored by the Museum and the Japan Society. Topics include "The Making of a Global Superpower: Japan's Modern Historical Experience"; "Japanese Society in Transition: Women and the Family"; "The Competitive Edge: Education for the 21st Century"; and "The Next Wave: Contemporary Japanese Architecture."

Dance programs will also celebrate Japan Month. Saeko Ichinohe and Company will present "Contemporary Dances Inspired by Japanese Traditions" on Sunday, January 5, at 2:00 and 4:00 P.M. At the end of the month, dancers from the Tachibana Nihon Buyo School in Tokyo will give their first United States performance of such classics as "Renjishi," or the Lion Dance. This group, together with the New York Tachibana Dance Company and the Soh Daiko drummers, will perform on Saturday, January 25, at 2:00 and 4:00 P.M.

These programs are free and will take place in the Kaufmann Theater. For a full schedule, call (212) 769-5315.

Asia's Giant Extinct Ape

In a joint American-Vietnamese venture in 1989, anthropologists uncovered Southeast Asia's oldest known human remains in the limestone caves of Thanh Hoa. Russell Ciochon, associate professor in the Department of Anthropology at the University of Iowa, will talk about this expedition, as well as future ones to uncover fossil remains of *Homo erectus* and the huge extinct ape *Gigantopithecus,* on Thursday, January 30, at 7:00 P.M. in the Museum's Main Auditorium. Tickets are $12 ($8 for members). Call (212) 769-5606 for ticket availability.

Totem Pole Carving

As part of the exhibition "Chiefly Feasts: The Enduring Kwakiutl Potlatch," Kwakiutl artist Richard Hunt will carve a twelve-foot totem pole in the Northwest Coast Indian Hall. He can be observed at work from Saturday, January 11, through Friday, January 31, between 10:15 A.M. and 5:00 P.M. (except on Wednesdays). As he works, Hunt will talk about his techniques and the role of totem carving in Kwakiutl society.

On two consecutive Thursdays, January 9 and January 16, aspects of the Kwakiutl potlatch will be presented. Gloria Cranmer Webster, director of U'Mista Cultural Center, will discuss the diversity of festive foods and ceremonials associated with the potlatch. Aldona Jonaitis, curator of "Chiefly Feasts," will talk about her experiences working with Kwakiutl villagers to create the exhibition. These programs will take place at 7:00 P.M. in the Kaufmann Theater. Tickets are $25 ($22.50 for members) for both evenings. For more information, call (212) 769-5305.

Primatology Grant

The Museum is one of five New York City institutions sharing a $1.6 million grant from the National Science Foundation for graduate study and research in primatology. The New York Consortium

Dancers from the Tachibana Nihon Buyo School Courtesy of Yoshie Tachibana

in Evolutionary Primatology will explore every facet of primatological study, including paleontology, behavior, ecology, genetics, and conservation. At least eighteen doctoral candidates and five postdoctoral fellows will be supported under the new program. Researchers will investigate wild primate feeding and locomotion, as well as human and primate fossil remains in sites around the world. This grant will allow students to take part in field studies abroad and internships at the five participating institutions.

At the Planetarium

Scientists monitoring weather systems from outer space have discovered hurricanes larger than the earth, dust storms forty miles high, lightning bolts that can vaporize cities, and snowstorms massive enough to stretch from New York to Paris. The new Sky Show, "Amazing Worlds of Weather," opens on Saturday, January 4. For information on schedules and admission, call (212) 769-5920.

Neil Tyson, a research associate at Princeton University, will present an illustrated talk, "Using Quasars to Probe the Unseen Universe," on Wednesday, January 22, at 7:30 P.M. He will discuss how quasars, believed to be the fiery nuclei of distant galaxies, are being studied to help solve the mystery of the nature and location of up to 90 percent of the mass of the universe. Tickets are $6 ($5 for members) and may be ordered in advance by sending a self-addressed, stamped envelope with payment to the Planetarium or purchased the night of the talk at the Planetarium box office. For more information, call (212) 769-5900.

Cochin Jews of India

Director-filmmaker Johanna Spector's film "Two Thousand Years of Freedom and Honor: The Cochin Jews of India" documents the history of these people, who arrived in Cochin, on India's Malabar Coast, as early as A.D. 72. The film will première in the Main Auditorium on Thursday, January 9, at 7:00 P.M. Tickets are $10 ($6 for members). For ticket availability, call (212) 769-5606.

These events take place at the American Museum of Natural History, located on Central Park West at 79th Street in New York City. The Kaufmann Theater is in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

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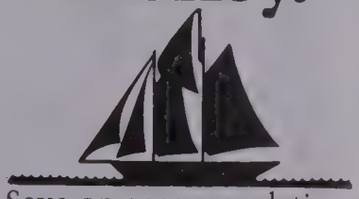

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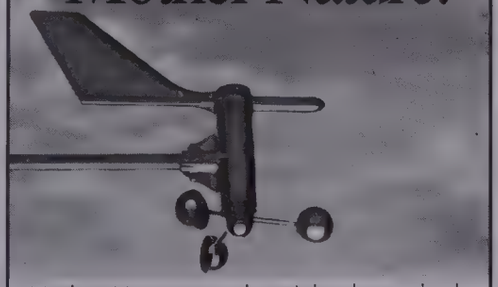

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Hops growing in Washington's Yakima Valley
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Flower of the Vine

Harvesting hop blossoms has its pleasures—and its perils

by Raymond Sokolov

On a brilliant sunny day last fall, I stood knee-deep in flowers, and their smell made me almost swoon. The flowers were a light yellow-green, with petals tightly closed to form a cone shape. These flowers would never fill any vase. No prom queen would wear them in a corsage, for they would soon be mechanically compressed into bales and shipped to industrial sites all over the country.

I was standing in a big processing center in the Willamette Valley south of Portland, Oregon, near Salem. The flowers were hops, grown not for their beauty but for the aromatic resin in the speck-sized yellow lupulin glands tucked under their petals.

Hop, *Humulus lupulus,* is a twining vine native to northern temperate areas of Europe, Asia, and North America. It is a member of the hemp family, the Cannabaceae, and its female flower is technically a sort of catkin composed of overlapping bracts—modified leaves that resemble petals (the red "leaves" of a poinsettia are bracts). The fruit of the hop is a seed-like structure known as an achene.

Some home gardeners grow hops as ornamental climbing perennials. The Anglo-American food writer Paul Levy has them covering part of a wall of his house in Oxford. In Portland, hops grow like ivy in the inner court of one of the innumerable small beer gardens that have become a distinctive feature of the city. This is a thoroughly logical choice of planting, since hops are an essential ingredient of beer brewing, and the hop industry (I hesitate to call it humuliculture) in this country is centered almost entirely in the states of Oregon and Washington.

In the previous century, hops were an important crop in New York, but powdery mildew wiped them out. So today, if an inquiring gastroethnographer wants to see a modern hop "yard," she or he has to go to the Pacific Northwest.

I arrived in late September, as the harvest was coming to an end. But there were still plenty of vines left, neatly attached to eighteen-foot-high wired trellises hung from wooden supports arrayed in long, orderly lines.

The Willamette Valley is a paradise of fecundity. One almost stumbles over stands of berries, stately dark groves of old hazelnuts, and new plantings of Asian pears. But in this pastoral picture, hop trellises are the leading motif. There is nothing quite like them in agriculture, and they are an imposing site—acres of these giant vines with their big, figgy leaves and their tight-clasped, conical flowers.

The harvest is also picturesque in its hybrid mix of the primitive and the mechanical. The basic idea is to strip away the vines and leaves from the cones. Then the cones are dried, to reduce the moisture level to less than 10 percent. Finally, the feather-light cones are compressed into bales.

A unique motorized hop picker moves through the trellis rows, culling the plants and transporting them by the truckload to a huge Rube Goldberglike cleaning apparatus that combines a sort of conveyor belt sieve-and-combing operation with the winnowing force of gravity to purify the crop and leave the hop farmer with nothing but flowers, stored in a large room with a heating unit under the floor.

Despite the intricate machinery that leads to this stage, hop farming is still built on human experience and skill. One of the most crucial factors in maximizing profit is the drying stage. It comes down to this: to reduce the natural moisture of the hops, minimizing the risk of spoilage and, there-

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by, increasing the useful shelf life of the cones. But the farmer does not want to reduce the moisture any further than necessary, because he is paid by weight. Wetter, therefore heavier, cones are more valuable than very dry, lighter cones (in other words, the more thoroughly dry the crop, the lower the price per cone). Farmers and brokers compromise on 10 percent as the ideal moisture content. In practice, a grower is delighted if he ends up with 9 percent moisture. Much money hangs on a percentage point or two. And it is the drying process itself that determines the difference.

You can still see workers spreading cones in even layers roughly knee-deep across the floor of drying rooms, but even this is often mechanized today. The process is called laying a floor, and the basic principle is evenness, no air pockets, so that the drying goes off uniformly and the moisture reduction is predictable.

Drying rooms are second-story affairs, high above ground level, because once the hops have been dried, they are dumped into deep holding areas where they cool overnight. The depth of these cooling chambers, something like twenty feet, is essential, because the compactor needs to work on a tall column of cones in order to produce a bale that is roughly the size of a person. Cooling rooms are not only deep but also broad; they hold many "floors" of cooling hops.

At first sight they are lovely to behold, like swimming pools filled with flowers, heady with the strange smell of heated hops. But in the old days, when people dumped the hops into these floral pits, they were places of fear. If you tripped and fell in, you died. The sea of weightless flowers would close around you. The smell of lupulin was asphyxiating. Struggle was useless. Unlike water, dried hops compress almost infinitely. There is nothing to swim against, no way to see through the waves as you drown in twenty feet of papery bracts.

At one time, knotted ropes hung from the walls of the cooling chambers. It was the only way to get out. Even if a friend saw you fall in, he couldn't dive in after you, because then he couldn't get out either. I talked to a man who did save someone once, with a long pole he managed to jab into the man's finger, the last part of him visible as he sank.

With mechanization, these accidents shouldn't happen anymore, yet somehow, this year a night watchman in Washington did "drown." No one can figure out how. But standing on the edge of a full room, I shuddered as I might have on the lip of an Alpine ledge.

I also wondered how brewers ever took to using hops as an additive in beer-making. No one I talked to and none of the sources I've found were able to point to a historical hops pioneer, some George Washington Carver who first persuaded brewmasters to put flowers in their wort. Nevertheless, the widespread use of hops in brewing does seem to be of fairly recent origin.

Hopping has occurred for at least a thousand years, but the practice became universal only about 150 years ago. Until then, hops were only one of several plants used to keep beer from spoiling: one source lists spruce ginger, ground ivy, sweet Mary, tansy, sage, wormwood, and sweet gale.

Creamed Hops

(Adapted from *The Belgian Cookbook*, by Nika Hazelton, Atheneum, 1970)

2 pounds hop shoots
Salt
Juice of 1 lemon
½ cup heavy cream
1 tablespoon butter
Black pepper
4 poached eggs

1. Cover the hops with lightly salted water acidulated with lemon juice and simmer until tender, about 10 minutes.
2. Heat heavy cream with butter until butter melts. Combine with hops in a deep serving dish. Add black pepper to taste. Top with poached eggs.

Yield: 4 servings

Hop Sprout Salad

(Adapted from *Bavarian Cooking*, by Olli Leeb, Kochbuch-Verlag, Munich, 1983)

2 pounds hop sprouts
Coarse salt
¼ cup light vinegar
White pepper
3 tablespoons oil
Chopped parsley

1. Rub the hop sprouts with coarse salt between your hands. Wash the sprouts.
2. In a large saucepan, boil the sprouts in 2 cups boiling water for 10 minutes or until tender. Drain, reserving liquid, and place hops in salad bowl.
3. Mix the hot cooking liquid, vinegar, and pepper and pour over sprouts. Let cool.
4. Add the oil and mix well. Sprinkle with parsley and let stand for at least one hour.

Yield: 8 servings

Hops have turned out to be a dependable, productive source of desirable bitterness, to counteract the sweetness of the malt grain from which beer is basically made. Modern chemistry, according to Charles Papazian's *The New Complete Joy of Home Brewing* (Avon, 1991), has also determined that hops have a beneficial effect on "head retention." Hopped beers hold their foam.

Connoisseurs and master brewers pay a lot of attention to hop varieties and hop concentrations. They have a crucial effect on the taste and character of beers. In Oregon, I heard a lot of arcane talk about new hop varieties, and I smelled several different strains, which really did have noticeably different aromas and obviously different appearances—in size, color, and shape. But I concluded that I would have to do a lot of home brewing to get a handle on what the aroma of a flower would yield in a fully brewed bottle of beer.

Papazian distinguishes between the bittering resins of the hops and the hop oils within the lupulin glands. It is the oils, he says, that give beer its flavor and bouquet. The oils are water soluble and highly volatile. Because their aroma can be easily boiled away, he adds them for a few minutes to the brew pot at the end of the brewing process.

There is a lot more to knowing how to hop beer—how much, which kind, and so forth—but anyone interested in actually brewing beer at home should consult Papazian's book or one of the numerous supply sources for amateur beermaking that have cropped up around the country.

My own ambition is limited to consuming hops themselves. I'm not talking about the flowers. I mean the tender spring shoots that emerge in March, before the vines have sent down their humongous taproots and turned woody and bitter above ground. Although I could find no one in Oregon who had ever tried to eat hop shoots, one grower suggested that it would be essential to earth over the shoots to prevent them from turning tough and bitter.

My interest in hop shoots is not some fanciful whim. I have been hearing for years about how they are a delicacy in Belgium, the capital of connoisseur brewing. There they are treated like asparagus or eaten creamed and with poached eggs on top. So if you are looking for a recherché excuse to visit northern Europe in the early spring, fly to Brussels and ask where to go for *jets de houblons*.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

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Trouble with Tribbles

"Star Trek" viewers, remembering the round, furry "tribbles" that overran the *Enterprise,* might be excused a sense of *déjà vu* on seeing this mob of spiny balls slowly jockeying for position as they devour a dead starfish.

The voracious diners are white sea urchins, five-toothed creatures about one and a half inches in diameter. Often found in aggregations of thousands, they slowly comb the ocean bottom for algae and organic detritus. So completely do white urchins strip the sea floor that the algae cannot regrow until the bottom-grazing "herds" are decimated by disease or starvation.

Photographed in a shallow bay near Mexico's Coronados Islands, just south of San Diego, California, the urchins are feasting on a partly dismembered sea star known as *Tethyaster.* In life, this starfish feeds on other invertebrates; when it dies, however, the predator may become dinner for urchins scavenging the ocean floor.—*R. M.*

Photograph by Chris Huss

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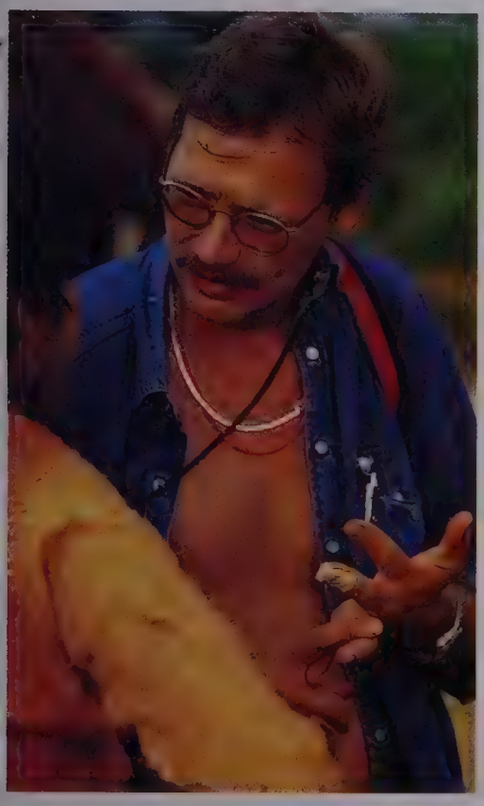
AUTHORS

Photographer **Chris Huss** (page 84) took his first underwater pictures when he was twelve, starting with an Instamatic camera wrapped in a plastic bag. Eventually he graduated to Nikon cameras, Ikelite underwater flashes, and scuba gear. He has dived all along the Pacific coast and has explored and photographed undersea habitats all over the Caribbean and the South Pacific. Diving in the Coronados, south of San Diego, California, and just off the Mexican coast, Huss saw a group of sea lions he wanted to photograph. "Swimming slowly, underwater, I headed toward the sea lions. All along the way I was distracted by armies of small white sea urchins ravaging the sea floor. Everything in their path was being devoured, reminding me of a horror movie." He photographed the urchins for this month's "Natural Moment" using a Nikonas 5 with a 15mm lens and an Ikelite 150 strobe at half power. Huss's underwater photos have appeared in many national and international magazines, books, and exhibits, winning sixty-two prizes and honors. To those seeking to learn his craft, he recommends *Howard Hall's Guide to Successful Underwater Photography* (Port Hueneme: Marcor Publishing, 1982).

Carol R. Townsend (page 40) has visited the Galápagos Islands a number of times as a lecturer with the American Museum's Discovery Tours. On her most recent trip to Isla Santiago, she had a chance to observe marine iguanas during the height of mating season in January. Most lizards will scurry for cover at the sight of a human, but according to Townsend, the marine iguanas were a pleasure to observe. The males paid no attention to her as she photographed their territorial battles. Townsend is currently an associate with the American Museum's Department of Herpetology and Ichthyology and researches the evolutionary history of unisexual lizards. For more information on the lives of Galápagos lizards, she recommends Michael Jackson's *Galápagos: A Natural History Guide* (Calgary, Alberta: University of Calgary Press, 1989).



A native of Sweden, **Kaj Århem** (page 46) first lived with the Makuna Indians of Colombia in the early 1970s. On a more recent visit he assisted filmmakers documenting the group for the series "Millennium: Tribal Wisdom and the Modern World," which will debut this spring on the Public Broadcasting System, the British Broadcasting Corporation, and Canada's Global Television Network. (The companion volume to the series will include photographs by Thomas L. Kelly.) A professor of social anthropology at Gothenburg University, Århem has also studied land use among the Masai of Tanzania. For additional reading he recommends *The Fate of the Forest: Developers, Destroyers and Defenders of the Amazon,* by Susanna Hecht and Alexander Cockburn (New York: HarperCollins, 1990); *The Fishes and the Forest: Explorations in Amazonian Natural History,* by Michael Goulding (Berkeley and Los Angeles: University of California Press, 1980); and *Makuna Social Organization,* by Kaj Århem, Uppsala Studies in Cultural Anthropology 4 (Stockholm: Almquist and Wiksell International, 1981).

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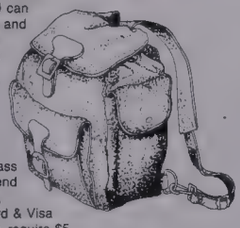

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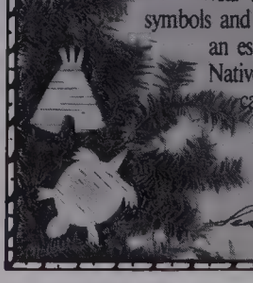

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For thirty years, **Bryan Nelson** (page 30), a native of Yorkshire, has been observing the gannets that nest off the coasts of the United Kingdom. He began this lifelong study under the renowned animal behaviorist Niko Tinbergen at Oxford University and received his doctorate there in 1963. Nelson is now retired as a reader in zoology at Aberdeen University in Scotland. Seabirds, and particularly gannets, have taken him to islands of the Southern Hemisphere, as

well as to the strongholds of the northern gannet near his home in Scotland. He has done fieldwork in the Galápagos, the Seychelles, and on Christmas Island. While on sabbatical in New Zealand in 1978, he became interested in comparing the communication systems of northern and Australasian gannets. His future research projects include further comparative studies of seabirds. A classic study of bird behavior is Niko Tinbergen's 1960 book *The Herring Gull's World* (New York: Lyons and Burford, reprinted in 1989). More on the behavior and body language of gannets can be found in Nelson's *The Gannet* (Vermillion: Buteo Books, 1978) and *Living with Seabirds* (Edinburgh: Edinburgh University Press, 1986).

Besides studying the impact of freezing on painted turtles, **Janet M. Storey** and **Kenneth B. Storey** (page 22) have explored biochemical adaptations in many animals, from anaerobiosis in intertidal organisms to hibernation in small mammals and estivation in land snails. Their research has taken them to the deep sea off Hawaii's Kona coast, up the Amazon River, and to the Adriatic seaside. Janet is a research associate at Carleton University's Institute of Biochemistry in Ottawa; Kenneth is a professor at the Institute and in the university's biology and chemistry departments. For additional reading, they recommend *Life in the Cold,* by Peter Marchand (Hanover: University Press of New England, 1987); "Frozen and Alive," by Kenneth and Janet Storey (*Scientific American,* December 1990); and *Turtles of the United States,* by Carl Ernst and Roger Barbour (Lexington: University Press of Kentucky, 1972).

On the beach at Grand Cayman, **James H. Marden** (page 54) entertains his daughter, Erica, with a seashell. In 1989, while Marden was in the Costa Rican rain forest studying the flight abilities of butterflies, his field experience was a mixture of relaxed enjoyment, boredom during rainy spells, and such unforgettable moments as stepping on a seven-foot boa while peering up into the forest canopy, being charged by a jaguar, and being visited by his wife, who announced that she was pregnant with Erica, their first child. Marden received a Ph.D. in zoology in 1988 from the University of Vermont and has worked in Panama and Namibia. He is currently a visiting assistant professor at Colgate University, where he teaches courses in animal physiology and ecology. Marden's other research interests include the behavior and physiology of territorial dragonflies and low-temperature flight in small insects. For additional reading he recommends *The Biology of Butterflies,* edited by Richard Vane-Wright and Phillip Ackery (Princeton: Princeton University Press, 1989).

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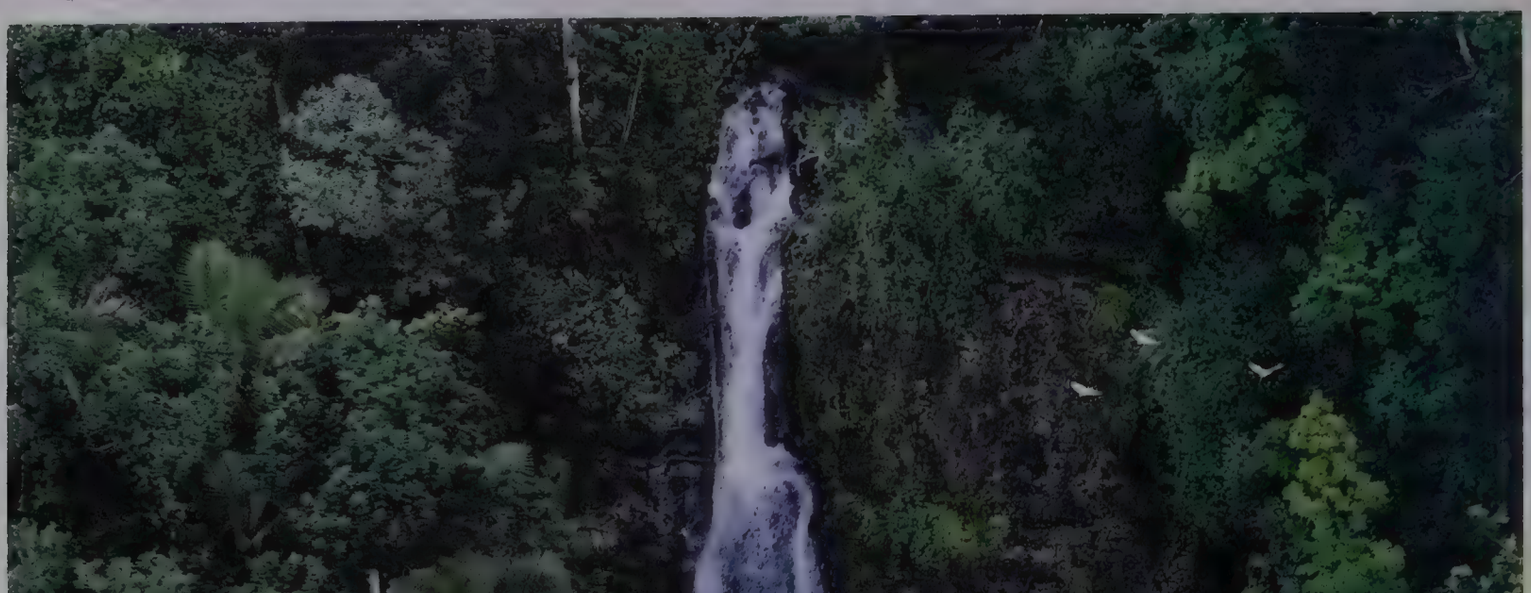

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NATURAL HISTORY

FEBRUARY 1992

COVER: *Colonial soft corals are among the longest lived of all creatures. A special section on aging begins on page 24. Photograph by Michele Hall, HHP.*

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24 ON THE NATURE OF AGING *Steven Austad*
Like death and taxes, it seems inevitable. We may first notice aging in our parents or our pets. But the inevitable dimming of the flame takes place in most living things. One exception: the organisms that trade off sex for eternal youth. In this special Natural History *section, assembled by senior editor Rebecca B. Finnell, eight scientists explore different dimensions of aging in many species including, naturally, ourselves.*

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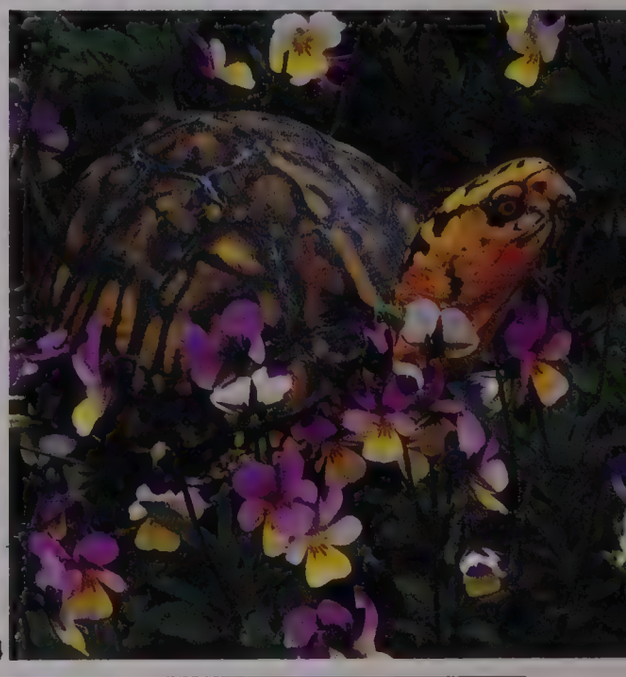

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Natural History (ISSN 0028-0712) is published monthly by the American Museum of Natural History, Central Park West at 79th Street, New York, N.Y. 10024. Subscriptions: $25.00 a year. In Canada and elsewhere outside U.S. $35.00 a year. Second-class postage paid at New York, N.Y. and at additional mailing offices. Copyright © 1992 by American Museum of Natural History. All rights reserved. No part of this periodical may be reproduced without written consent of *Natural History*. Send subscription orders and undeliverable copies to the address below. Membership and subscription information: Write to address below or call (800) 234-5252 (urgent). POSTMASTER: Send address changes to Natural History, Post Office Box 5000, Harlan, IA 51537-5000

Sweet Death

Genes that used to help us survive starvation may be causing the current diabetes epidemic in well-fed westernized societies

by Jared Diamond

For my wife and me, taking our five-year-old twin sons to the supermarket means traversing a minefield of dietary dangers. Among breakfast foods, my kids are tempted by the choice between Apple Cinnamon Cheerios and Froot Loops, respectively 85 percent and 89 percent carbohydrate according to their manufacturers, with about half of that carbohydrate in the form of sugar. Boxes picturing the famous turtles with Ninja powers seduce children to ask for Teenage Mutant Ninja Turtles and Cheese Pasta Dinner, 81 percent carbohydrate. Snack choices include Fruit Bears (93 percent carbohydrate, no protein) and Teddy Graham's Bearwich chocolate cookies with vanilla cream (71 percent carbohydrate); both list corn syrup, as well as sugar, among their ingredients. All of these foods contain little or no fiber. Compared with the diet to which our evolutionary history adapted us, they differ in their much higher content of sugars and other carbohydrates (71 to 95 percent instead of about 15 to 55 percent), much lower protein and fiber content, and in other respects. I mention these particular brands, not because they are unusual, but precisely because their content is typical of what is available.

With foods like these so popular, it is no wonder that most *Natural History* readers will die of diet- and life-style-related diseases, including diabetes, the commonest disease of carbohydrate metabolism. Granted, diabetes isn't infectious or rapidly fatal, so it doesn't command press headlines, as does AIDS. Nevertheless, the world epidemic of diabetes today eclipses the AIDS epidemic in its toll of death and suffering. Diabetes disables its victims slowly and reduces their quality of life. Among its secondary consequences, it is the leading cause of adult blindness in the United States, the second leading cause of nontraumatic foot amputations, and the cause of one-third of our cases of kidney failure. The estimated number of diabetics in the United States ranges from 4 to 12 million people; worldwide, the number is probably more than 100 million people.

The most prevalent form of diabetes arises from the collision of our old hunter-gatherer genes with our new twentieth-century life style. It thereby serves as a model for other noncommunicable diseases, such as heart attack, stroke, and cancer, that have similarly catapulted in frequency to become the leading causes of death in westernized societies. But how did genes that produce a serious disease become so prevalent, despite the ongoing operation of natural selection to eliminate harmful genes? Could it be that the genes now giving us diabetes were actually good for us before our plunge into the modern life style?

You may recall that the primary manifestation of diabetes is high concentrations of the sugar glucose in the blood, with the result that glucose spills over into urine. From this manifestation stems the disease's full name, diabetes mellitus, based on the Greek words meaning "running-through of honey." About 10 percent of cases in the United States represent so-called juvenile-onset, or type I, diabetes, in which the body destroys the pancreatic cells that produce the hormone insulin. This form of diabetes is distinct not only in its cause and treatment but also in its evolutionary origins (a subject I'll save for another piece). For now, I'll discuss in-

stead only the commoner form of diabetes, the so-called adult-onset form, or type II, which appears with increasing frequency mainly in adults past the age of thirty, and to which I'll henceforth refer simply as diabetes.

Here is what normally happens when we consume some glucose (or other glucose-containing carbohydrate). As the sugar is absorbed from the intestines, its concentration in the blood rises, signaling the pancreas to release insulin. The insulin in turn signals muscle and liver and fat cells to take up the glucose (thereby halting the rise in blood glucose) and store it as glycogen or as fat, to be used for energy between meals. Other nutrients, such as amino acids, also trigger the release of insulin, and insulin has effects on food components other than sugar (such as preventing the breakdown of fat).

The hallmark of adult-onset diabetes is that body cells become resistant to the insulin signal and fail to take up glucose. As long as the pancreas can respond by releasing more insulin, the cells' resistance can be overcome and the blood glucose remains within the normal range. But if the pancreas can no longer overcome that resistance, the blood glucose rises, glucose spills into the urine, and diabetic damage to kidneys and eyes and other tissues gradually develops. That damage is the result, at least in part, of those chronically high levels of blood glucose.

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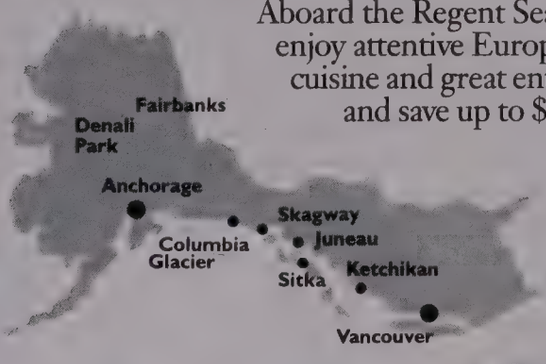

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rephrase by saying that diabetes involves both genetic and environmental factors. Evidence for a role of genes includes the increased risk of getting diabetes, ten times higher, if you have a diabetic first-degree relative than if you don't. Further evidence is that, in Western society, the so-called concordance for diabetes between identical twins, who are identical in their genes, is very high. That is, usually either both twins develop diabetes or neither does. In fraternal twins, who share only half of their genes, such concordance is correspondingly lower. While these observations are compelling evidence for genetic predisposing factors, the exact molecular effect of the diabetes-producing genes is not yet known.

But diabetes also depends upon environmental factors. Even if you are genetically predisposed to diabetes, you won't necessarily get the disease, as would be the case if you carried a pair of genes for muscular dystrophy or Tay-Sachs disease. And the risk of developing diabetes does increase with age, and with having diabetic first-degree relatives, and with being born of a diabetic mother, which we can't do anything about. But other risk factors that predict diabetes are under our control, including being overweight, how much we eat, and what we eat. Most diabetics (I emphasize again, most adult-onset diabetics) can reverse their symptoms by minimizing those risk factors—especially by reducing their consumption of concentrated sugar and fat and total calories, and thereby losing weight.

The same environmental risk factors that predict diabetes in individuals also predict it in whole populations, hence the worldwide rise in those risk factors underlies the current worldwide epidemic of diabetes. Disease rates have recently been shooting sky-high in many groups of migrants whose move shifted them from a vigorous Spartan life style to a sedentary one based on abundant supermarket food. A dramatic example involved the Yemenite Jews who were airlifted to Israel by Operation Magic Carpet in 1949 and 1950, and were thereby plunged abruptly from medieval conditions into the twentieth century. Although Yemenite Jews were almost free of diabetes on reaching Israel, 13 percent of them then became diabetic within two decades. Other migrants who sought opportunity and instead found diabetes include Mexicans and Japanese moving to the United States, Polynesians moving to New Zealand, Chinese moving to Mauritius, and Asian Indians moving to Fiji, South Africa, and Britain. Still other peoples who experienced westernization of life style while remaining in their original homelands similarly developed diabetes, including many Native American groups, native (aboriginal) Australians, and Micronesians and Polynesians.

These proofs of an environmental role in diabetes are illustrated by the tragedies of the two peoples with the highest rates of diabetes in the world: Pima Indians and Nauru islanders. To consider the Pimas first, they survived for more than 2,000 years in the deserts of southern Arizona, using agricultural methods based on elaborate irrigation systems, supplemented by hunting and gathering. Because rainfall in the desert varies greatly from year to year, crops failed about one year in every five, forcing the Pimas then to subsist entirely on wild foods, especially jack rabbits and mesquite beans. Many of their preferred wild plants were high in fiber, low in fat, and released glucose only slowly; thus they represented an ideal antidiabetic diet. After this long history of periodic but brief bouts of starvation, the Pimas experienced a more prolonged bout of starvation beginning in the nineteenth century, when white settlers diverted the water supply on which their agriculture depended. Today, they eat store-bought food.

Observers who visited the Pimas in the early 1900s reported obesity to be rare and diabetes almost nonexistent. Since the 1960s, obesity has become widespread among the Pimas, some of whom now weigh more than 300 pounds. Half of them exceed the U.S. ninetieth percentile for weight in relation to height. Pima women consume about 3,160 calories per day (50 percent over the U.S. average), 40 percent of which is fat. Associated with this obesity, Pimas have achieved notoriety in the diabetes literature by now having the highest frequency of diabetes in the world, nineteen times that of U.S. whites. Half of all Pimas over age thirty-five, and 70 percent of those at age fifty-five to sixty-four, are diabetic.

The case of Nauru, a small, remote island in the tropical Pacific, is only slightly less extreme. Nauru islanders used to work hard to feed themselves by fishing and gardening, until it was discovered that Nauru rock has the world's highest concentration of phosphate, an essential ingredient of fertilizer. Nauru today is independent, and its per capita wealth, derived from phosphate revenues, is among the world's highest. Nauru citizens get little exercise, eat double their recommended calorie intake, shop in supermarkets, and heap their shopping carts with big bags of sugar. The incidence of diabetes among Nauru adults has now reached an epidemic 33 percent, ten times the U.S. rate and topped only by the Pima epidemic.

The Nauru islanders and Pima Indians, and the many other peoples whose existence suddenly became westernized as a result of either migration or new conditions at home, experienced a characteristic suite of linked simultaneous changes in life style and diet. All these peoples became less active physically. They increased their average daily calorie intake. Their food consumption became more regular: they ate three meals a day, eating each time until they were full, instead of eating whatever was available whenever they could get it. More of their calories came to be in the form of sugar and fat (especially saturated fat), and less in the form of complex carbohydrates and fiber. They consumed more salt. All these factors are so inextricably linked in the phenomenon we call westernization that it is unclear which particular ones have caused the resultant epidemic of diabetes.

Clearly, though, new factors of the Western life style unmasked effects of preexisting genes, since the consistent result has been diabetes within a few decades or less—far too rapid to attribute to altered gene frequencies. The role of preexisting genes is well illustrated by studies carried out on the Mexican population of San Antonio, Texas. Modern Mexicans arose from the mixture of Mexico's pre-1500 Indian population with white Spaniards who began to arrive with Cortés in 1519. Depending on the particular town, or even suburb, in Mexico where one looks, one can still find local populations that are largely white and others that are largely Indian, as indicated by genetic and other markers. The Mexican populations of three different neighborhoods of San Antonio, estimated to be on the average 46 percent, 27 percent, and 18 percent Indian in their genes, have been compared with each other and with Anglo white Texans (0 percent Indian). The frequency of diabetes turns out to fall in the same sequence: 15 percent, 10 percent, 5 percent, and 3 percent. Even after controlling for obesity, the frequency remains several times higher in Mexicans than in Anglos.

This parallel between the frequency of diabetes and the estimated proportion of Indian genes suggests that genes predisposing under westernized conditions to diabetes occurred at a higher frequency in Mexico's native Indian population than in Spanish immigrants. The same conclusion emerges from comparisons of diabetes rates and white admixture among Native Americans in North Dakota, Nauru islanders, and native (aboriginal) Austra-

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L E N O X . S I N C E 1 8 8 9 .

lians. Recall that westernized Japanese, Chinese, Asian Indians, and Polynesians also suffer higher diabetes rates than do equally obese or lean westernized Europeans living in the same towns. For whatever reason (I'll speculate in a moment), this hints that diabetes-predisposing genes are now less frequent among Europeans than among many other populations.

This brings us to an obvious question: why did genes leading to such a debilitating disease come to be so common among so many human populations? If rates of diabetes were as low as those of muscular dystrophy (about 1 in 10,000), the genes' frequency could be explained as nothing more than the product of a recurring mutation: that is, babies with a new mutation being born at the same rate as older bearers of such mutations die of the disease. However, no mutation occurs so frequently as to appear anew in 3 to 50 percent of all babies, the actual frequency range for diabetes in westernized societies. We must instead assume that the genes now predisposing to diabetes must actually have been favored by natural selection before our sudden shifts to a westernized life style. What good did diabetes-linked genes formerly do for us, and why do they get us into trouble now?

Recall that the net effect of the hormone insulin is to permit us to store the food that we ingest at meals and to spare breakdown of our accumulated fat reserves. Thirty years ago, these facts inspired geneticist James Neel to speculate that diabetes stems from a "thrifty genotype," making its bearers especially efficient at storing dietary glucose as fat. For example, perhaps some of us have especially hair-triggered release of insulin in rapid response to a small rise in blood glucose concentration. That genetically determined quick release would enable those of us with such a gene to sequester dietary glucose before its blood concentration rose high enough that glucose began to spill over into our urine.

Today, when many of us regularly consume high-sugar meals and rarely exercise, such a gene is a blueprint for disaster. We become fat; our pancreas releases insulin constantly until it loses its ability to keep up or until our muscle and fat cells become resistant; and we end up with diabetes. But consider how almost all people lived throughout human evolution until recently. Instead of three predictable, unlimited, sugar-rich meals each day, frequent food shortages and rare gluts were the pattern of life. For example, several times in the course of my fieldwork in New Guinea, a group of New Guineans and I went virtually without food for several days, as a result of the failure of my arrangements for food delivery to our campsite. The first time this happened, when we reached a remote but empty campsite at sunset after a hard all-day climb, I expected to be lynched on the spot. Instead, my New Guinea companions were philosophical: "Orait, i no gat kaikai, yumi sleep nothing" ("OK, so there's no food, we'll just sleep on empty stomachs"). Conversely, every year or two my New Guinea friends manage to have a gluttonous feast lasting several days, when food consumption shocks even me (rated by my friends as a bottomless pit) and a few people die of overeating.

Under these traditional conditions of starve-and-gorge existence, those people with a thrifty genotype would be at an advantage, because they could store more fat in surplus times and hence better survive subsequent starvation. Among Pima Indians, only those with the thriftiest metabolisms could survive their regular bouts of starvation every five years, or their longer bout of starvation when whites cut off their water supplies. The Micronesian and Polynesian populations of all remote Pacific islands, including Nauru, are descended from survivors of long canoe voyages, in the course of which many emigrants died and only those initially the fattest survived. The same starve-and-gorge cycles in less extreme form molded modern hunter-gatherers, such as native Australians, and many modern peasant farmers, such as Asian Indians, Japanese, Chinese, and Native Americans besides the Pima. To most humans until recently, our modern Western fear of obesity and our diet clinics would have seemed ludicrous.

Thus, genes that today predispose us to diabetes may formerly have helped us to survive famine. Animal experiments support the plausibility of this hypothesis. Laboratory mice with genes for diabetes survive starvation better than do normal mice. Zoos recognize diabetes as a big problem for their captive monkeys, whose lazy existence and regular feedings are the monkey equivalent of the All-American life style.

However plausible, this line of reasoning doesn't entirely explain why today's white Europeans have a relatively low frequency of diabetes-predisposing genes, when most Europeans too lived as peasant farmers until recently. The simplest answer may be that current developments among the Pimas and Nauru islanders are telescoping into a single generation the life style changes that developed over the course of many centuries in Europe. We refer to our indolent, obese, supermarket-based life style as Western precisely because it arose first among Europeans and white Americans and is only now spreading to other peoples. Perhaps diabetes-related genes have been undergoing elimination in Europe for centuries, as a result of many infants of diabetic mothers dying at birth, diabetic adults dying younger than other adults, and orphaned children and grandchildren of those diabetic adults dying of neglect. Alternatively, Europeans and Middle Easterners may have derived less advantage from a thrifty genotype ever since the rise of agriculture, if that area's diversity of planted crops, domestic animals, and fish made starvation a less acute threat than elsewhere in the world.

I said at the outset that I view diabetes as a paradigm of modern death. People used to die mainly of infectious diseases and violence. Now, the leading killers in the West are noncommunicable diseases that are almost unknown among hunter-gatherers and peasant farmers. Besides diabetes, these new killers include heart attack, stroke, hypertension, and cancers of the lung, colon, and cervix. As I previously reasoned in the case of hypertension (*see* "The Saltshaker's Curse," *Natural History,* October 1991), all these new killers arise from the collision between our old genes and our new life style—a collision in which our bodies come off the losers.

Yet we're not inevitably the losers, because we ourselves created the new life style. Some help will come from molecular biological research, aimed at linking particular risks to particular genes, and hence at identifying for each of us the particular dangers to which our particular genes predispose us. However, society as a whole doesn't have to wait for such research. It is already clear what changes would minimize many (though not all) risks for most of us. Those changes include: not smoking; exercising regularly; limiting our intake of total calories, alcohol, salt, sugar, and saturated fats; and increasing our intake of fiber, calcium, and complex carbohydrates.

This advice is so banally familiar that it's embarrassing to repeat it. Repetition merely reemphasizes that the sweet death of diabetes, and other leading twentieth-century killers, kill us only with our own permission. The words of Ralph Waldo Emerson, written in another context, apply as well to dietary sugar today and to diabetes-linked genes yesterday: "Every sweet has its sour, every evil its good."

Jared Diamond studies evolutionary biology and teaches physiology at UCLA Medical School.

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Mozart and Modularity

How could a mere child be so transcendent in one arena but so ordinary in all other ways?

by Stephen Jay Gould

Daines Barrington (1727–1800), an English lawyer and wealthy member of the lesser nobility, published so many short articles on such a variety of subjects that he could scarcely avoid a reputation as a dilettante. In numerous communications to the Royal Society of London, he discussed the landing place of Caesar in Britain, the nonuniversality of Noah's flood, the antiquity of playing cards, and the death of Dolly Pentreath, the last native speaker of Cornish (an extinct branch of the Celtic languages). Some of his colleagues considered him superficial and overly credulous. One detractor even composed a heroic couplet in his dishonor:

> Pray then, what think ye of our famous Daines?
> Think of a man denied by Nature brains!

Then, in 1764, Barrington happened upon something truly important. But stung by rebukes for his previous carelessness and hyperbole, he proceeded cautiously. He waited six years before publishing his observations as a note in the *Philosophical Transactions of the Royal Society of London,* Britain's leading scientific journal, then and now. And he began his article by invoking the classical literary form for understatement—litotes. (These Greek terms for parts of speech and forms of rhetoric have paralyzed generations of schoolchildren who can't remember the difference between a dactyl and a synecdoche. Monty Python got back at professorial pedants by making great merriment with "litotes" and its improbable sound.) Litotes (from the Greek *litos,* meaning "small" or "meager") is a form of understatement that expresses an affirmative by the negative of its contrary—as in "not bad" for "good." In his opening paragraph, Barrington used litotes in a near apology to readers for taking their time:

> If I was to send you a well attested account of a boy who measured seven feet in height when he was not more than eight years of age, it might be considered as not undeserving the notice of the Royal Society.

In his second paragraph, Barrington sneaked up a bit further upon his actual discovery:

> The instance which I now desire you will communicate to that learned body, of as early an exertion of most extraordinary musical talents, seems perhaps equally to claim their attention.

The third paragraph, although only in historical retrospect, drops the bombshell:

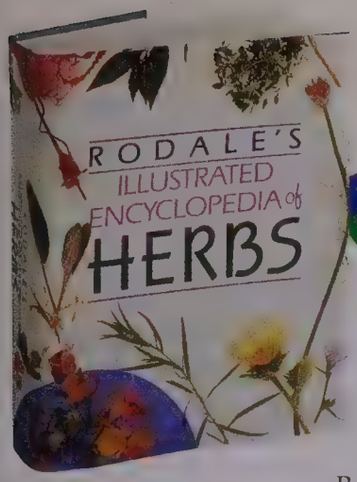
> Joannes Chrysostomus Wolfgangus Theophilus Mozart, was born at Saltzbourg [*sic*] in Bavaria [*sic* again], on the 17th of January, 1756 [*sic* thrice, for Mozart was born on January 27].... Upon leaving Paris [in 1764 at age eight] he came to England, where he continued more than a year. As during this time I was witness to his most extraordinary abilities as a musician, both at some publick concerts, and likewise by having been alone with him for a considerable time at his father's house; I send you the following account, amazing and incredible almost as it may appear.

Litotes had ceded to overt wonderment.

Mozart's skills were so astounding that Barrington even doubted his extreme youth; could father Leopold's game be an elaborate ruse, passing off a well-trained adult midget as a young son? Barrington delayed publication for six years until he could obtain proof in the form of Mozart's birth certificate from the register of Salzburg, "procured from his excellence Count Haslang, envoy extraordinary and minister plenipotentiary of the electors of Bavaria and Palatine" (you just gotta believe somebody with a title like that).

Leopold Mozart made quite a business of showing off his precocious son. Barrington, graced with a private visit, proceeded as any intellectual would: he tested eight-year-old Wolfgang for a variety of musical skills in reading, memory, and improvisation, and his letter to the Royal Society is a report of his impressions. (I learned about this publication at a special exhibit of the British Museum. Barrington's article, entitled "Account of a very remarkable young musician," appeared in 1770, in volume 60 of the *Philosophical Transactions.* The notion that young Mozart had served as subject for a scientific paper in England's leading journal was too much to resist for this forum. What better symbol could we possibly advance for the fruitful interaction of art and science?)

One issue, above all, intrigued Barrington as he observed Mozart and affirmed in spades all the reports he had heard about the young child's precocity (for Barrington sought, in this article, to plumb the nature of genius itself, not merely to explicate Mozart, who, remember, was then just a remarkable little boy, not yet an icon of Western achievement): apparent "wholeness" must be decomposable into separate modules, each subject to inde-



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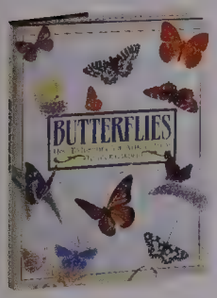

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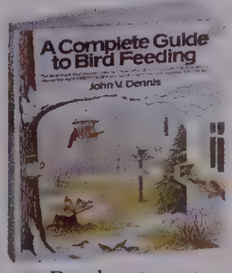

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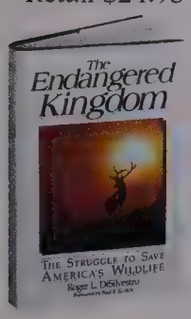

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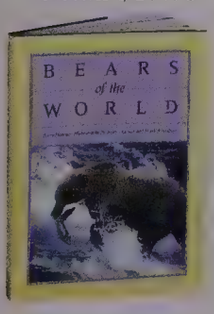

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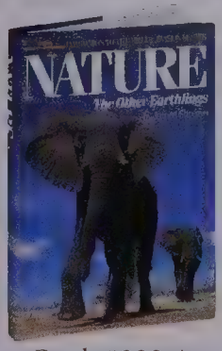

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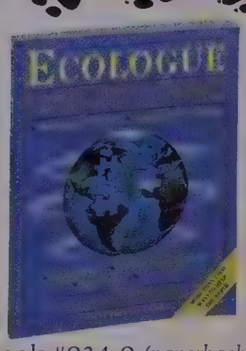

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pendent development. How else could a mere child be so transcendent in one particular arena but ordinary in all other ways? This idea of dissociability must provide a key to understanding human talents: genius is not integral but must result from a hypertrophy of particular modules.

Barrington cites two examples of dissociation in grasping the nature of genius. First, he marvels at Mozart's musical sophistication in an otherwise ordinary and rambunctious eight-year-old boy. If young Wolfgang had been a miniature adult, as adept in manners as in music, then genius might be portrayed as integral, but he acted like an ordinary kid in all areas outside his special talent:

> I must own that I could not help suspecting his father imposed with regard to the real age of the boy, though he had not only a most childish appearance, but likewise had all the actions of that stage of life. For example, whilst he was playing to me, a favorite cat came in, upon which he immediately left his harpsichord, nor could we bring him back for a considerable time. He would also sometimes run about the room with a stick between his legs by way of horse.

Second, Barrington gained some insight about the dissociability of basic emotions. He asked Mozart to improvise songs expressing particular emotions—a song of love and a song of anger. Again, Barrington took refuge in litotes to express his wonder at the successful result:

> [The love song] had a first and a second part, which . . . was of the length that opera songs generally last: if this extemporary composition was not amazingly capital, yet it was really above mediocrity, and showed most extraordinary readiness of invention.

The song of rage was even more dramatically successful:

> This lasted also about the same time with the Song of Love; and in the middle of it, he had worked himself up to such a pitch, that he beat his harpsichord like a person possessed, rising sometimes in his chair.

But how could an eight-year-old boy, with presumably limited experience, at least of sexual love, so abstract and distill these basic modules of our emotional repertoire? This could only be possible, Barrington reasoned, if the fundamental emotions themselves are genuinely dissociable packages. Our totality must be an amalgam of separable components.

We have, before and ever since, been fascinated with such "splinter skills"—extraordinary talents in otherwise undistinguished or even severely handicapped people—for the same reason that so intrigued Barrington: such dissociation seems to argue for a separate origin and causation of talents that we would prefer to view—but cannot on this evidence—as expressions of a more general genius. We all know the standard examples of chess grandmasters who cannot balance their check books and mentally handicapped people with prodigious skills in apparently instantaneous numerical calculation or reckoning the day of the week for any date over centuries or millennia.

For all the criticism that Barrington received as an injudicious dilettante, this time he chose well—both in subject and argument. For the principle of dissociation, and construction from separable modules, is central to our understanding of any complex system that arises by natural evolution. Barrington chose the right issue for his wonderment—and the breadth of application extends well beyond divine Mozart to the evolution of any complex organism and the structure of mind. Integral wholeness may sound warm, fuzzy, and romantic, but dissociability is the necessary way of the world.

Since principles are often best illustrated by exposing the fallacy of their contraries, I present the most important, and probably most intelligent, argument ever raised against evolution by a great scientist in the turbulent generation before Darwin. In the *Discours préliminaire* to his four-volume work on fossil vertebrates, published in 1812, Georges Cuvier denied the possibility of evolution by affirming the doctrine of intrinsic and nondissociable wholeness.

Cuvier designated his principle as "the correlation of parts," maintaining that all features of an organism are intricately designed and coordinated to function in a certain optimal way. No part can change by itself. Any conceivable alteration in one organ would require the redesign of every other feature, for optimal function requires complete integration:

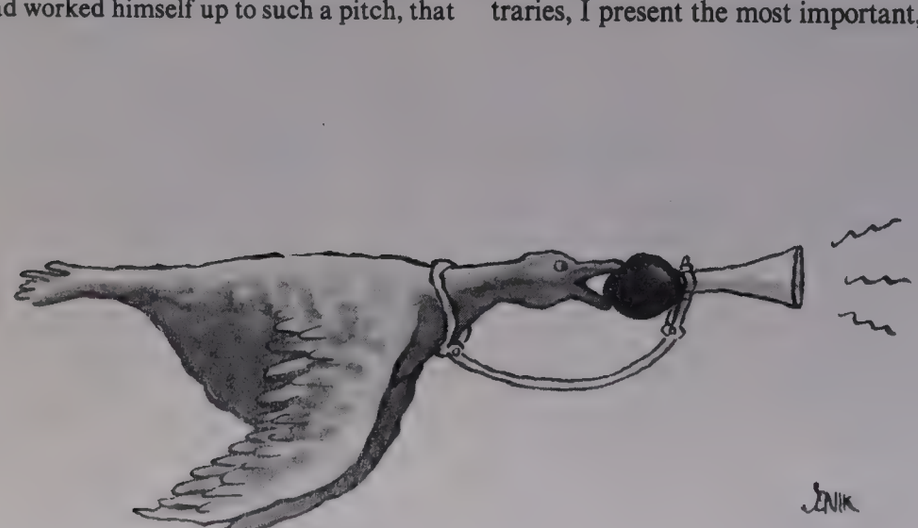
> Every organized individual forms an entire system of its own, all the parts of which mutually correspond, and concur to produce a certain definite purpose, by reciprocal reaction, or by combining towards the same end. Hence none of these separate parts can change their forms without a corresponding change in the other parts of the same animal, and consequently each of these parts, taken separately, indicates all the other parts to which it belonged.

As the last phrase shows, Cuvier used this principle primarily to argue that he could reconstruct entire organisms from fossil fragments, since one bone implied a necessary shape for all others (see my column of June 1990). But Cuvier had a second and even grander motive—the denial of evolution. How can transmutation occur if parts cannot alter separately or at least with some degree of independence? If each tiny modification required a redesign of every other feature, then inertia itself must debar evolution. How can we imagine a coordinated change of all parts every time some minute advantage might attend a slight alteration in one feature? Cuvier continued:

> Animals have certain fixed and natural characters, which resist the effects of every kind of influence, whether proceeding from natural causes or human interference; and we have not the smallest reason to suspect that time has any more effect upon them than climate.

I call this argument intelligent because its logic is impeccable. If parts were not dissociable, then evolution could not occur. "All for one" might be good morality for a Musketeer but cannot describe the pathway of natural change in complex systems.

Logical arguments are only as good as their premises. The chain of inference may be irrefutable, but if the premise be false, then the conclusion must fail as well. To cite the harsh motto of our computer



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age: GIGO, or garbage in, garbage out (no matter how phenomenal the inner workings of the machine).

Cuvier's logic was correct, but his premise of total integrity is false. Evolution does proceed (as it must) by dissociating complex systems into parts, or modules, made of a few correlated features, and by altering the various units at differing rates and times. Biologists refer to this principle as "mosaic evolution," and we need look no further than the history of our own species. Human ancestors, like Lucy and her early australopithecine cousins, evolved an upright posture of nearly modern design before any substantial enlargement of the brain had occurred.

This cardinal principle of dissociability works just as well for the mental complexities of emotions and intelligence as for designs of entire bodies. As he began to compile the notes that would lead to his evolutionary theory, Charles Darwin recognized that he could not give an evolutionary account of human emotions without the principles of modularity and dissociation.

He wished, for example, to trace facial gestures to antecedent states in ancestral animals. But if the human set is an integrated array, locked together by our unique consciousness, then a historical origin from simpler systems becomes impossible. Darwin recognized that two principles must underlie the possibility of evolution. First, gestures cannot be subject to fully conscious control; some, at least, must represent automatic, evolved responses. As evidence for ancestral states, Darwin cited several gestures that make no sense with our modern morphology but that must have served our forebears well. In sneering, we tighten our upper lips and raise them in the region of our canine teeth. This motion once exposed the fighting weapons of our ancestors (as it uncovers the long and sharp canines in many modern mammals that perform the same gesture), but human canines are no bigger than our other teeth and this inherited reaction has lost its original function.

Second, just as young Mozart could separate and abstract single emotions, Darwin realized that standard facial gestures must be modules of largely independent action—and that the human emotional repertoire must represent a concatenation of separate links rather than facets of an unbreakable totality. Evolution can mix, match, and modify independently. Otherwise we face Cuvier's dilemma: if all emotions are inextricably bound by their status as interacting, optimal expressions, then how can anything ever change?

Late in his life, Darwin wrote an entire book on this subject, *The Expression of the Emotions in Man and Animals* (1872). But his youthful jottings in the so-called M Notebook of 1838, hastily scribbled in the months before he codified his theory of natural selection in September of that year, are even more compelling for their telegraphic expression of excitement in discovery and novel explanation. Darwin later labeled this notebook as "full of Metaphysics on Morals and Speculations on Expression." His notes on emotional gestures center on modularity and its importance for evolutionary explanation. Each feeling is linked to a gesture (often quite complex); we have limited control over the form of a gesture, and its evolutionary meaning must often be sought in a lost ancestral function. Darwin wrote:

> He may despise a man and say nothing, but without a most distinct will, he will find it hard to keep his lip from stiffening over his canine teeth.— He may feel satisfied with himself, and though dreading to say so, his step will grow erect and stiff like that of turkey. . . . With respect to sneering, the very essence of an habitual movement is continuing it when useless,—therefore it is here continued when . . . uncovering the canine [is] useless.

Darwin then speculates on the further evolution of emotions treated as separate entities. He argues that sighing is still directly useful in humans "to relieve circulation after stillness." Yet we might retain the gesture as a sign for an accompanying emotion even if the physiological benefit disappeared: "If organization were changed, I conceive sighing might yet remain just like sneering does."

I received my clearest insight into the modularity of facial expressions not from any scientific writing but from viewing the

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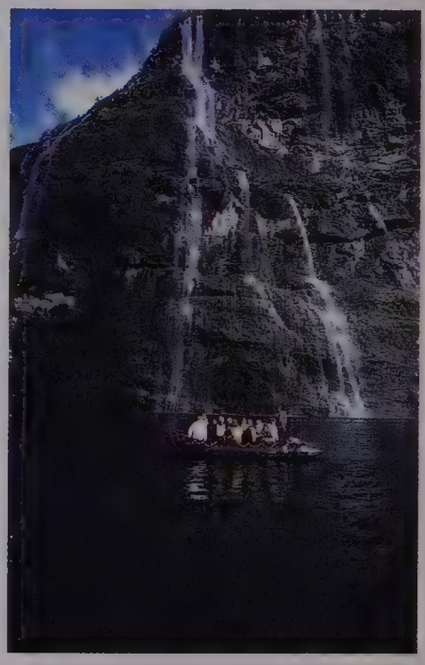

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world's greatest sculpture: Michelangelo's Moses in the church of San Pietro in Vincoli (Saint Peter in Chains), in Rome. Moses, bearing the tablets of the Ten Commandments, has just come down from Mount Sinai. Suffused with holiness and with joy at the gift he may now bestow upon his people, he looks around only to see the Israelites worshiping the golden calf. His face is a maelstrom of emotions: zeal and ardor for what he has witnessed on the mountain, rage at his people for their transgression, deep sorrow for human weaknesses. The sublimity of the statue lies in the richness of this mixture upon one face—as if Moses is truly Everyman (and in every major state of feeling).

I visited this statue several times and felt its power but could not grasp how Michelangelo had put so much into one face. On my last trip, and largely by chance, I think that I found a guide to the solution. Michelangelo understood—whether viscerally or explicitly, I do not know—the principle of modularity. When I focused on one feature and covered the rest of the face, I saw only one emotion each time. The eyebrows speak one message, the nose another, the lips a third. The rich face can be decomposed into modules of feeling, but the totality stuns us by integration.

Many of the most famous experiments in animal ethology affirm and extend the principle of modularity. Consider Niko Tinbergen's classic work on begging for food in newly hatched gulls (so beautifully described in his charming book *The Herring Gull's World*). The newborns peck vigorously at their parent's beak, apparently aiming for a red spot near the tip of the mandible. If an infant makes proper contact, the parent regurgitates a parcel of food and the baby gull gets its first meal.

But what inspires the pecking behavior? The baby gull has no conscious understanding of a reward to be gained. It has never eaten before and cannot know what a knock on a parent's bill will provide. The behavior must be innate and unlearned.

At what, then, does the baby bird direct its pecks? At first consideration, one might conjecture that the entire form or gestalt of the parent would provide an optimal target. After all, what could be more appealing than the parent's totality—a full, three-dimensional image with the right movements and odors. But consider the issue a bit more deeply: the hatchling has never seen a bird. Can the complexities of the entire parental form be engrafted innately upon its untested brain? Wouldn't it be more reasonable—easier to program if you will—for the hatchling to respond to one or a few abstract particulars, that is, to modules extracted from the total form?

In an exhaustive series of experiments, Tinbergen showed that hatchling gulls do respond to modules and abstractions. They peck preferentially at long and skinny things, red things, and regions of markedly contrasting colors. As an effect of this simplified modularity, they hit the red spot at the tip of the parental bill—the only red region at the end of a long object, in an area of contrasting color with surrounding yellow. Complex totality may be beyond the cognitive capacity of a hatchling gull, but any rich object can be broken down to simpler components, and then built up. Any developing complexity—whether in the cognitive growth of an individual or the evolution of a lineage—may require this principle of construction from modules.

If a hatchling gull favors abstraction (and doesn't perceive parental totality), then Tinbergen reasoned that he might construct a "super-gull"—a model exaggerating the key modules. This "improved" version might elicit more attention than the actual parents themselves. This idea bore fruit as hatchlings preferred several rather un-gull-like dummies to real birds. For example, narrow sticks longer than real bills, and color patches more starkly contrasted with surroundings than the red spot on an actual bill, elicited more pecks from hatchlings than did an accurately modeled head.

Tinbergen then generalized these observations to the important concept of a "super-normal stimulus"—an artificial exaggeration that elicits more favor or response than the feature itself. (In his book, Tinbergen includes an amusing discussion of his struggle to find a good name for this phenomenon. He first spoke of a "super-optimal" stimulus but finally rejected the term as oxymoronic—for, by definition, optima cannot be exceeded. He then remarks that " 'supernatural' would be a good term, if it were not used already in another sense." Finally, he settled upon "super-normal.")

Many animals exploit this modular principle of supernormal stimuli to gain advantage over others. In the classical example, cuckoos subvert the propensities of their hosts to feed any chick in the nest that rises higher, squawks louder, or opens its beak wider. The mother cuckoo lays its egg in another bird's nest. The egg itself is an accurate mimic and often can't be distinguished from the host's own products. But the cuckoo hatchling quickly outstrips its nestmates in growth and may even toss them out to their death. The unwitting adult hosts, fooled by the supernormal stimuli arising from the large, loud cuckoo chick, continue to feed the usurper and murderer.

Obviously, if modularity didn't often

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rule over accurate perception of totalities, supernormal stimuli would not exist. Host parents would know their own children and reject the cuckoo. Hatchling gulls would peck at parental beaks (that might feed them), rather than at cardboard dummies with exaggerated features.

Modularity pervades all neurological organization, right up to what Darwin called "the citadel itself"—human cognition. This principle of breaking complexity into dissociable units does not disappear at the apex of known organization. We might not be fooled in toto by the analog of a cuckoo chick, but the fashion industry knows how well, and how sheepishly, we respond to a plethora of supernormal stimuli.

Interestingly, Darwin accompanied his M-notebook jottings on the modularity of emotional gestures with similar statements about cognitive items and units:

> People who can multiply large numbers in their head must have this high faculty, yet not clever people.... The great calculators, from the confined nature of their associations (is it not so in punning) are people of very limited intellects, and in the same way are chess players.... The son of a fruiterer in Bond St. was so great a fool that his father only left him a guinea a week, yet he was inimitable chess player.

The concept of modularity, explicitly so called, lies at the heart of much innovative research in cognitive science. The brain does a great deal of work by complex coordination among its parts, but we have also known for a long time that highly particular aptitudes and behaviors map to specific portions of the cerebral cortex. The modules are often stunningly precise and particular, as illustrated by unusual losses and misperceptions of people who have suffered damage to highly localized regions of cortex (*see* Oliver Sacks's wonderful book *The Man Who Mistook His Wife for a Hat*). The September 19, 1991, issue of *Nature* tells the remarkable story of two men who suffered localized strokes that seriously impaired their ability to use and recognize vowels, but not consonants. Surely, we would have regarded our separation of sounds into vowels and consonants as an artificial division of a totality—yet this distinction may record a deeper mapping of cerebral modules (*see* R. Cubelli, "A selective deficit for writing vowels in acquired dysgraphia," *Nature,* vol. 353, pp. 258–60).

Mozart was not yet Mozart when Daines Barrington witnessed his incredible performance. He was just a bratty kid at the acme of precocity. In fact, Barrington even speculated on his potential for future contributions. He spoke of another prodigy named John Barratier who knew Latin at four, Hebrew at six, and who translated the travels of Rabbi Benjamin, complete with learned notes and glosses, at eleven. But we know little of Barratier today because he died before the age of twenty.

Barrington notes the unhappy tendency of geniuses to die young, and he expresses his hope for Mozart by comparing him with England's greatest musical guest, the German emigré Handel. Young Handel may not have been quite so precocious as Mozart, but he did live a long and remarkably productive life, from 1685 to 1759, and Barrington took comfort:

> I am the more glad to state this short comparison between these two early prodigies in music, as it may be hoped that little Mozart may possibly attain to the same advanced years as Handel, contrary to the common observation that such *ingenia praecocia* are generally short lived.

Barrington got half his wish. Mozart lived long enough to become Mozart but died so young, at thirty-five, that his early demise has become the canonical example of a genre—the tragic and uncertain lives led by so many artists. (I learned of Barrington's article in an exhibit marking the bicentennial of Mozart's death. I write this essay during the month of the anniversary itself. I wish that I were composing this at the proper Handelian distance of forty years hence, which would be good for Mozart and good for me too.)

Daines Barrington thought that he was writing a scientific article about the modularity of human abilities. The later exaltation of Mozart makes us view his work in a more particular light—as a testimony about the early life of everyone's favorite musical prodigy. Is Barrington's article part of science or of art? Perhaps, for once, these are truly false modules, and our intellectual life would benefit by more integration. If Mozart had died before *Idomeneo* (his teen-aged opera), Barrington's article would endure as a respectable scientific account of a generic musical prodigy. I thank God for *Don Giovanni* (I even thank Him for every Musak rendition of *Eine Kleine Nachtmusik*). But even if Mozart had died in childhood, in the frosts of an English winter (in their damned buildings without central heating), his contribution to our understanding of the human mind would be no mean thing, no small potatoes.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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The Vikings and the Eskimos

Did Bjarni Herjolfsson discover America?

by Samuel M. Wilson

The Vikings, the Scandinavian mariners who plundered European coasts from the eighth through the tenth century, are not remembered for their gentle manners. The *Groenlendinga Saga,* one of the Norse heroic narratives, begins by telling how, because of some killings, Thorvald and his son Erik the Red left Norway for Iceland. By this time, A.D. 982, Iceland was extensively settled. Erik married Thjodhild, and they had a son, who bore the name Leif Eriksson. After more killings, expulsion from one town and fights with other men at another, Erik was banned from Iceland.

He fitted out his ship for sea in Eiriksvag, and told the people there that he meant to look for the land that Gunnbjörn Ulf-Krakuson had sighted when he was storm-driven west across the ocean—Gunnbjarnarsker, or Gunnbjörn's Skerries. He would be coming back, Erik said, to get in touch with his friends should he discover that land [retold from *The Norse Atlantic Saga,* translated by Gwen Jones, Oxford University Press, 1986].

In A.D. 984, Erik the Red found the land Gunnbjörn had described, and set out to build a new colony: "He called the country he had discovered Greenland, for he argued that men would be drawn to go there if the land had an attractive name."

Sixteen years later, a prosperous and widely traveled Norse captain named Bjarni Herjolfsson sailed from Europe to Iceland, where he was in the habit of spending every other winter with his father. On his arrival that winter, however, Herjolfsson found that his father had sold his farm and gone to Erik's colony on Greenland, and so he followed in his fifty-foot sailing ship. He had no map of the route or compass (nor did anyone else at that time), and he was going to a place he had never been. He ran into bad weather and was swept to a coast that did not answer to the formidable descriptions of the mountains and glaciers of Greenland.

Bjarni Herjolfsson had found the coast of Labrador, the easternmost part of continental North America, a land covered with forests and low hills. But he was looking for his father, not a New World, so he turned around without landing and sailed two days back to Greenland. This makes Bjarni Herjolfsson the first European on record ever to have seen the New World, and about the most forgotten name in the history of the "discovery" of the Americas (among those whose names we do know). The five-hundredth anniversary of Herjolfsson's voyage would have fallen only eight years after Columbus landed in the Caribbean. But neither Columbus—who traveled to Iceland on one of his early voyages as a merchant seaman—nor anyone else among the fifteenth-century scholars and sailors interested in sailing west across the Atlantic was aware of Herjolfsson or his discovery.

Herjolfsson told the story of his detour to Erik and others, and later Leif Eriksson went to explore this new coast. Not to be outdone by his father's euphemistic labeling of Greenland, Leif called the place Vínland hit góda, or "Wineland the good," although wine grapes could not possibly grow there. (Some argue that this wild exaggeration results from a mistaken transmission of the Norse sagas, whereby *vin,* or "grassland," was confused with *vín,* "wine").

On Vinland, the Vikings discovered people, whom they called Skraelings (barbarians). Just who these people were has been a subject of scholarly debate. They may have been arctic sea people—Eskimos or their predecessors—but archeologist Robert McGhee proposes that they were Algonquian-speaking Indians of the Atlantic northeast, who could have traveled this far north each summer. Whoever these Skraelings were, the first recorded interaction between New World and Old World people was a disaster—and almost eerily prophetic for subsequent European-Indian interactions. Leif lent his ship to his brother Thorvald, who sailed for the North American coast. Thorvald found a large, flat headland on a forested bay, walked around for a while, and declared, "This is a lovely place, and here I should like to make my home."

Then they made for the ship, and saw three mounds on the sands up inside the headland. They walked up to them and could see three skin-boats there, and three men under each. So they divided forces and laid hands on them all, except for one who got away with his canoe. The other eight they killed, and afterwards walked back to the headland, where they had a good look around and could see various mounds on up the fjord which they judged to be human habitations.

Act 1, scene 2 of the encounter of two worlds begins an hour or two later, after Thorvald and his men have had a nap:

"Rouse ye, Thorvald, and all your company, if you would stay alive. Back to your ship with all your men, and leave this land as fast as you can!" With that there came from inside the fjord a countless fleet of skin-boats and attacked them.

Although Thorvald was killed in this battle, he turns up in later stories, one indication that the sagas are far from reliable historical documents. They were often written down centuries after the events they describe took place. But the archeological site of L'Anse aux Meadows, on the northern tip of the island of Newfoundland, testifies unequivocally to the Norse presence there.

The attempts to colonize Vinland lasted a few more years after Thorvald's misadventure but ultimately were unsuccessful. According to the sagas, the venture was doomed by Skraeling hostility and internal fighting among the Norse. Possibly Vinland was also just too far away from

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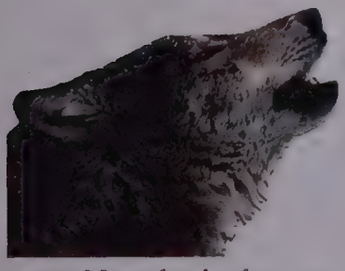

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Greenland, Iceland, and the Norwegian homeland for a colony to survive there. Greenland ultimately suffered the same fate, but more slowly.

According to the testimony of the Norse sagas, Erik the Red did not find people on the southern tip of Greenland, only "habitations of men, fragments of boats of skin, and stone artifacts, from which it may be seen that the same kind of people had passed that way as those that inhabited Vinland, whom the Greenlanders called Skraelings." Apart from this observation, there is very little mention of interactions with New World people on Greenland in the early years. The *Historia Norvegiae* (a history by an unknown author written about A.D. 1170) records fights with the Skraelings about A.D. 1150, and there are early descriptions of them as "horribly ugly, hairy, and swarthy, with great black eyes." For the most part, however, until the final days of the Norse colonization of Greenland, in the 1400s, the island's cohabitants are scarcely mentioned.

The Skraelings whom the Vikings first encountered on Greenland, or at least those who shared the island with the Norse for most of the time that followed, were the Eskimos. Historians and archeologists concerned with this era call them the Thule; their modern-day descendants are more properly known as the Inuit. By coincidence, both the Thule and the Norse had reached Greenland at about the same time, setting to work to colonize the island as a new extension of their territory. Neither were Greenland's first settlers, however: people had already lived there for nearly 3,000 years.

The first colonizers of Greenland did not head for the relatively mild southern tip chosen by the Norse, but instead colonized the northern tip, the most northerly bit of land in the world. Lying just 450 miles from the pole, the land is now called Peary Land, after the admiral. When they arrived, these first inhabitants were already well adapted to life above the Arctic Circle, making tools that archeologists assign to the arctic small tool tradition. They lived in small tents (less than ten feet in diameter) during both winter and summer and moved their settlements often. Unlike the later Thule, however, they preferred to hunt land mammals such as musk ox and caribou instead of sea mammals, and the archeological evidence that they used dog sleds and kayaks is equivocal.

In Greenland and the eastern part of arctic North America, these early inhabitants slowly transformed their life style and material repertoire into what archeologists call the Dorset tradition. These "Paleo-Eskimos" hunted both land and sea mammals, occupying some settlements for longer and longer periods. Dorset artifacts are more like those that Thule and later Inuit of the northern ice might have used—dog sleds, shoes for snow and ice, kayak parts, large knives similar to those used more recently to make snow houses, or igloos, and harpoons for hunting seals, walruses, and even larger arctic sea mammals.

The earliest Vikings to reach Greenland may have encountered people of the Dorset tradition, but the latter may have already been replaced by the Thule, who were moving from west to east. The origins of the Thule people are obscure, but the similarity of their culture to that found in the western Arctic suggests that they traveled from Siberia, the Bering Strait, and northern Alaska across 5,000 miles of frozen coasts, pack ice, glacial outlets, seasonal passages of open water, and hundreds of islands of the Canadian Arctic. Their superior adaptation to the arctic environment allowed them to cross this territory in a few centuries or less, displacing or assimilating the local groups they

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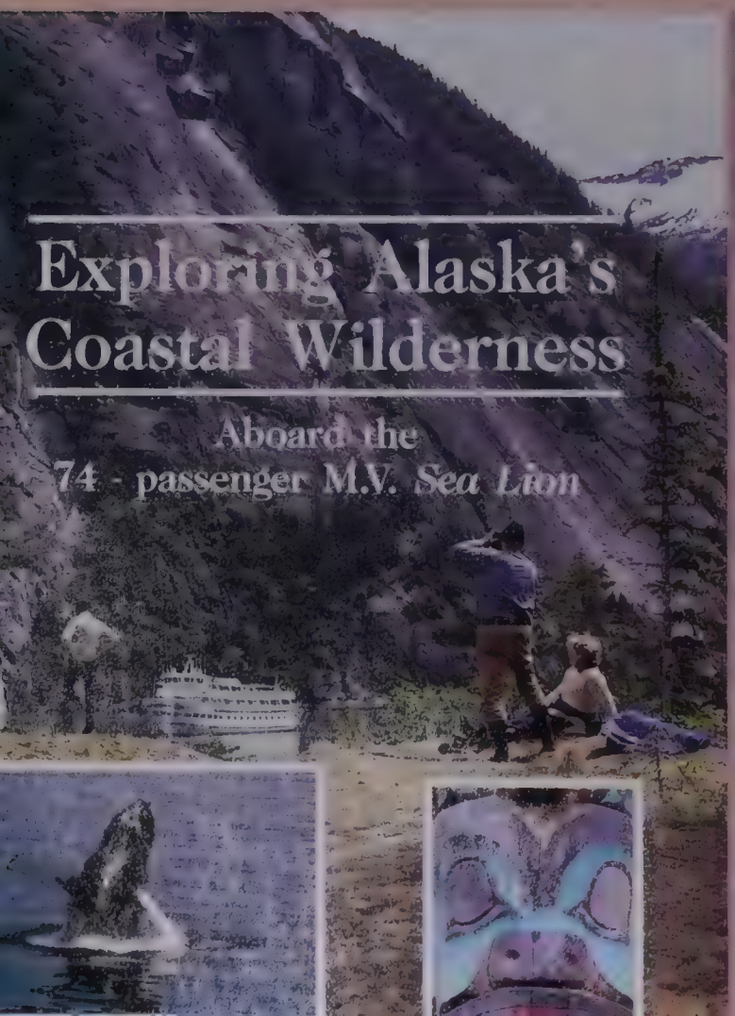

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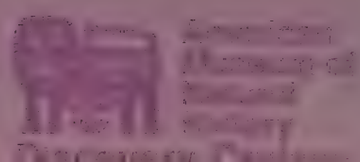

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encountered. The Thule were emphatically sea people, hunting seals, walruses, and especially baleen whales (their favorite was the bowhead whale, which averages forty feet in length and weighs about forty tons).

There is good archeological evidence for Thule settlements on the coast of Greenland by A.D. 1100 and some suggestion that the first Thule migrants arrived even earlier. Don Dumond's interesting and readable book *The Eskimos and Aleuts* (Thames and Hudson, 1987) puts Thule people on Ruin Island off the coast of northern Greenland before A.D. 1000. And Moreau Maxwell, in *Prehistory of the Eastern Arctic* (Academic, 1985), discusses the carbon-14 dating of the early Thule expansion and suggests that the dates for the first wave of immigrants might be in the 900s, rather than the 1000–1100 date usually assumed (although he also warns that radiocarbon dating in the Arctic is a very tricky business). According to Maxwell, one of the surprising points

is the evidence emerging since the 1970s of strong Norse contact. Since the Norse sagas refer to voyages no farther north than Upernivik (73° north latitude) and then only in the fourteenth century, it had long been assumed that Thule sites with metal objects must have been late in the sequence. It is now clear that the Norse were penetrating northwards at least as far as 79° north latitude less than 50 years after the initial Norse settlement of Brattalid [Erik's farm] on southern Greenland.

Other recent archeological research shows Thule settlers moving steadily down the coasts from northern Greenland, trading walrus ivory for European goods.

The Norse colony in Greenland consisted of two scattered settlements, Brattalid and other homesteads to the east and another group sixty miles to the west. What became of them? The question has been debated since the colony failed. Archeologist Thomas McGovern examines the question from many angles in a fascinating article, "Cows, Harp Seals, and Church Bells: Adaptation and Extinction in Norse Greenland" (*Human Ecology,* 1980). He looks at fluctuating global climate, the Norse economy, the hierarchical organization of their society, and their interactions with the Thule. The question that underlies his discussion is, why did the Norse hold so strongly to unsuccessful European ways, when the Thule offered an ever-present example of better ways of surviving in Greenland?

McGovern says that several factors are involved. For one thing the Norse economy worked all right when the climate was good but was unstable when it deteriorated after 1200, during the period of global cooling known as the Little Ice Age. Ultimately he blames the demise of the colony on the Greenlander elite, who held the outpost to old and ineffective ways until it could no longer survive.

A report from about 1340 says that "now the Skraelings have the entire West Settlement; but there are horses, goats, cows and sheep, all wild. There are no people, neither Christians nor heathens." Did the Skraelings kill all the colonists? It is doubtful, for even though their relations were sometimes violent, they had lived side by side for a long time, the Thule near the mouths of the fjords and the Norse deeper within. More likely, the colony grew smaller and smaller and less able to sustain itself, while events in northern Europe made Scandinavian traders less willing to cross the dangerous Atlantic to trade with those who remained. The colony is last mentioned in documents from 1409, and the archeological evidence suggests that the eastern settlement was completely deserted by the end of the 1400s.

The descendants of the Thule, the Inuit, eventually occupied all of Greenland's coast. They took Admiral Peary to the North Pole and still live on the island.

Samuel M. Wilson teaches anthropology at the University of Texas at Austin.

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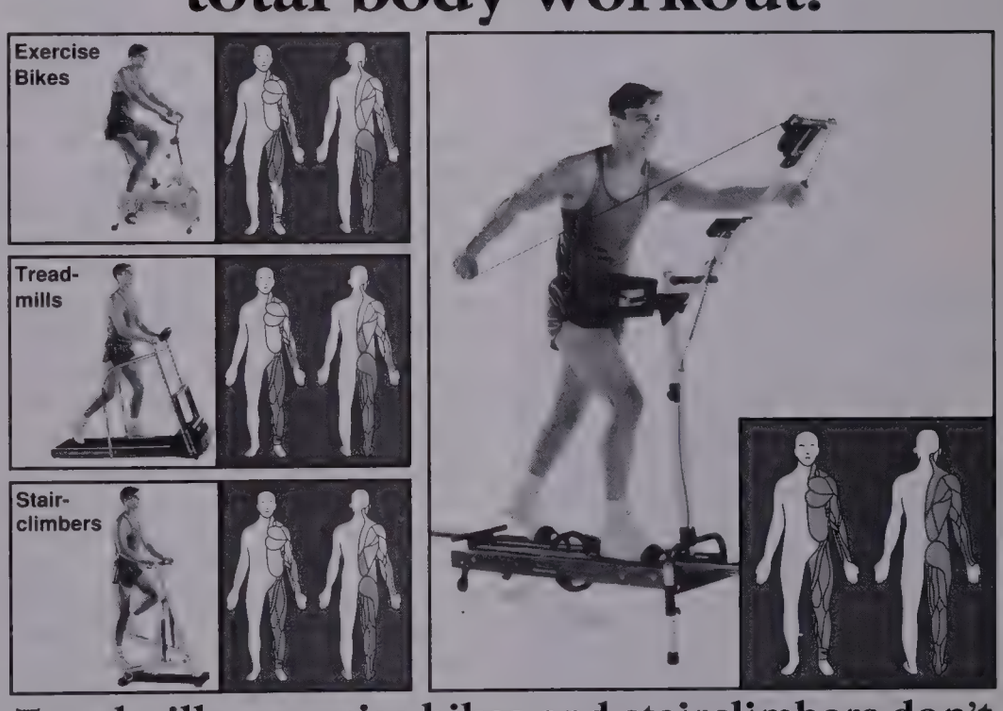

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The Ice Man Dawdleth

What took the Bronze Age so long?

by Roger L. Welsch

Anyone who knows me will agree that I have shown remarkable restraint in not dedicating one of these columns to a discussion of the recent theory that dinosaurs were driven to extinction, not by cold, starvation, meteors, or Ninja turtles, but by their own flatulence. As if that were not enough—for those of us who seek the wellsprings of humor, at any rate—the theory continues that we humans may be approaching a similar fate because we feed beet silage and molasses cakes to cattle. Loving liver and onions as I do, I find it difficult to pass up a straight line like that, not to mention the poetic justice of it all.

But that's okay. It's not as if I haven't had other opportunities to explore the issue. I don't spend all my life sitting at a word processor, and you can bet that the fellows up at the Chew 'n' Chat Café observe no artificial restraints in their investigations of current scientific concerns. In fact, I'll bet we have spent more time the past few months here in Dannebrog talking about dinosaur indiscretions than have all the paleontologists, ecologists, and flatuologists in all the universities west of the Missouri River.

Second only to dinosaur flatulence at the village think tank has been the topic of the Bronze Age man discovered not long ago, thawing from glacial ice between Austria and Italy after four thousand years in the freezer, give or take a millennium. Over coffee and pancakes at the café, we ordinary men and women have wrestled with the same questions puzzling scientists: Where was the Ice Man, as he has come to be known, going? What was he doing? Who was he? How did he die? What is the meaning of the possessions he was carrying with him? There are as many theories as questions.

Just the other morning, Mick the Carpenter, Luke the Assistant Carpenter, Woodrow the Plumber, my wife (Lovely Linda), and I were settling international problems over breakfast, and Woodrow tapped his forefinger on the latest article about the Ice Man in the local newspaper: "It says here, the Ice Man was wearing soft leather shoes stuffed with grass. Those are après-ski boots, sure as shootin'. And this guy was alone. My theory is that the dude was just off the ski slopes and was waiting for a shuttle to take him to the nearest singles bar."

Mick picked up the newspaper, scanned it a moment, and said, "Aha! You're wrong. It says here he had a little bag with some flint and grass in it, obviously a primitive cigarette lighter. This poor pilgrim had already arrived at the bar. He almost certainly was about to light up a smoke, was hassled by some nonsmokers, stepped outside to get them off his back, and froze to death, a victim of misguided health nuts." Mick pulled out a cigarette and his lighter, tacitly daring the nonsmokers among us to murder him by sending him and his cigarette out into the Nebraska cold, considerably more of a threat than any Tirolean glacier.

CeCe, the waitress and café enforcer, leaned over Woodrow's shoulder, took a look at the newspaper item, and offered, "It says here he is an Ice Man. The mystery is solved: his mother told him, 'You're a nice man, son. Why don't you go out and find yourself a nice girl?' "

CeCe realized at once that with that groaner she canceled whatever chance she had of getting a tip from the morning tightwads, so right away she reloaded and fired again: "Actually, since he's a man, he probably just got lost and was too dumb to ask directions. Rather than lower himself and admit he was lost, he preferred to sit down on a glacier and die."

"No," Luke said by way of a rejoinder to CeCe—a risky venture. "I'm betting this poor guy's wife got a headache and sent him to the drugstore for some aspirin in the middle of an Ice Age night when even saber-toothed tigers and mammoths knew enough to stay at home by the fire."

"Oh boy," sighed Woodrow. "This article lists everything the Ice Man had with him, and there's no mention of aspirins. That means the drugstore was closed by the time he got there and he never got them. Can you imagine the explaining he'll have to do when he gets home?"

At that point Lovely Linda spoke up. Now, when Linda steps up to the microphone, folks pay attention. She is quiet, shy, pretty, darn near fragile, but she has, as the more diplomatic say around here, a way with words. Men who have crossed verbal swords with her, or, more accurately, tried to cross verbal swords with her, exit the occasion wishing they had taken on something a lot more fun—like wrestling a wounded grizzly bear with cubs or checking out a big sale at Victoria's Secret. Linda can be that tough.

For example, last summer we hired ML&W (Mick, Luke, and Woodrow) Construction to add a room to our house. They promised to have the work done in six weeks. Alas, they were still camped on the shady side of our house, cutting boards and bending nails, four months later. Mick and Luke were always busy, but nothing much was getting done. When they did finally finish the room, however, the work was excellent and so, as we surveyed the finished product, I said, "You know, you guys should take some photos of this room and post them in lumberyards all around the area. You'd have work for the rest of your life."

"And," Linda said softly, "that's if you only get one job." Later, up at the café, Mick, Luke, and I agreed that not one of us had ever heard such loud silence in the 137 years of our collective lives.

So, when Lovely Linda cleared her throat during the Ice Man discussion the other day, she had an immediate, if apprehensive, audience. "I think," she said to no one of us in particular, "that the scientists are wrong about the hatchet and knife the Ice Man was carrying. Same with the sticks and points they're calling bows and arrows. And the string bag and little rock. They are not weapons; they are tools—a hammer, a plane, a plumb bob, drill bits."

Linda paused. My three friends were leaning forward, hanging on Linda's every word, anxious to hear the rest of this thesis she had obviously thought about before. "This guy was a carpenter, dawdling around on his way to work, and when they analyze the contents of his stomach, they're going to find out he was full of pancakes and bacon and coffee. And what's worse, somewhere not far from where he was found, sooner or later they'll find a petrified Iron Age woman still sitting in her Bronze Age house, waiting for Handy Andy there," she pointed archly at the picture of the withered mummy in the paper, "to show up and finish her kitchen."

"Well," said Mick the Carpenter after what seemed like about a week and a half, "I guess I'll be moving along. Lots to do."

"Yes," chimed in Luke. "If I'm going to pick up the lumber and nails for you over at Peterson's, I better get hustling. Yessirree."

"Yep," chirped Woodrow, hardly waiting for Luke to finish his contribution. He looked at his pocket watch with dramatic panic. "Whoa! Time's a-wasting, and time's money." And the three almost got crushed passing through the café's narrow door jamb all at the same time.

Spending too much time thinking about the latest scientific developments can be downright dangerous. In fact, I'll bet that's what happened to the Ice Man. He was making his way from the local café to that lady's kitchen, with the very best intentions of getting something done that day. And then he got to wondering, "Whatever happened to all those dinosaurs?"

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

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Once they have returned from the sea
and spawned, sockeye salmon age and di
within a matter of days.
Art Wolfe

This special section of *Natural History* was prepared by senior editor Rebecca B. Finnell.

On the Nature of Aging

by Steven Austad

One of the most painful lessons of my childhood was that pets live more quickly than humans. My dog Spot (I called all my pets Spot, regardless of whether they were, in fact, spotted), who was a puppy when I was a toddler, had become decrepit by the time my hormones began to flow as a teenager. Arthritic, weak-sphinctered, virtually deaf and blind, Spot died a "natural death" before I went off to college. People who keep pet hamsters discover that their pets reach a similar state of advanced decrepitude in about three years.

Although humans live longer than dogs and hamsters, the general pattern of their lives follows fundamentally the same trajectory. Soon after puberty, we begin to decay physically. The signs of deterioration are subtle at first and are probably best noted in athletes, whose physical performance is monitored closely. By thirty-two, no one's reflexes are as quick as at twenty-five. To say that by forty an athlete has lost a step is a considerable understatement. Simultaneously, endurance wanes and the frequency of injuries increases. Soon, evidence of deterioration begins to show up even in nonathletes. We all recover more slowly from infections. Kidneys, liver, and heart operate less efficiently. We require stronger and stronger aids to maintain reasonable sight and hearing. Vague aches and pains multiply.

Aging—and by that I mean deteriorating through time (also known as

Aging

In general, the larger the mammal, the longer the life span. African elephants may live as long as seventy years.
Frans Lanting; Minden Pictures

senescence) rather than simply growing older—is a nearly ubiquitous biological phenomenon, and it so constantly confronts us that I'm surprised more people don't perceive it as a central biological mystery. Perhaps its very ubiquity makes it appear less puzzling. We tend to think of ourselves and other animals in the same way we think of machines: wearing out is simply inevitable.

Yet biological organisms are fundamentally different from machines. They are self-repairing: wounds heal, bones mend, illness passes. Why, then, should they be subject to the same sorts of wear and tear as machines? Furthermore, why should some animals, like dogs and hamsters, deteriorate comparatively quickly, and others, such as tortoises, sharks, monkeys, and humans, do it more slowly?

One way to compare aging in different species is to look at the longest-lived animals in a population. Presumably, these exceptional individuals die purely as a consequence of physiological decay. By this measure of absolute longevity, some of the most slowly aging animal groups are sturgeons, turtles, seabirds, condors, elephants, and the egg-laying mammals (platypuses and echidnas). There are good records of sturgeons living for more than 150 years. Even some invertebrates are considerably longer lived than one might expect. Earthworms can live for more than a decade, tarantulas for several decades, and from the number of annual growth rings they have, some clams appear to live in excess of 200 years.

These kinds of comparisons tell us little, however, about how long animals of different species tend to live, on average, in the wild. Better measures of aging are the rates at which certain demographic traits change with age: basically, in an aging animal, the risk of dying increases and the rate of reproduction declines. To understand why this is so, we need first to look at what animals die of.

Death, of course, is an ever-present danger, even for a nonaging animal. In the real world, people and animals often die

THE LONG AND THE SHORT OF IT

A fly's life span depends on how fast the insect spends its oxygen allowance

by Robert G. Allen

Houseflies that hatch in summer live only about three weeks, while those that emerge in the cooler days of fall slow down dramatically during the winter and often live more than six months. Similarly, worker honey bees live thirty-five days in summer, while winter bees live eight months. Early in the twentieth century, researchers discovered that even when various types of insects were kept under different sets of conditions designed to alter their life span, each generation consumed the same total amount of oxygen over a lifetime. In fact, closely related species of insects (such as mosquitoes, houseflies, and fruit flies) consume similar amounts of oxygen per gram of living tissue during their lives.

To many scientists, these observations suggested that the rate of oxygen consumption, or metabolic rate, influenced how long insects lived and that there was an upper limit to the amount of oxygen they consumed in a lifetime. This limit, usually called the metabolic potential, is believed to be determined genetically.

Insects have been popular for studying metabolic influences on life span because altering their rate of oxygen consumption is very easy: in warmer environments, they become more active, breathe more quickly, and live less long than in cooler environments. The metabolic potential, however, does not change. Longer-lived insects consume the same amount of oxygen as shorter-lived ones; they simply consume it more slowly, thus taking longer to reach their metabolic potential.

In some species of insects, even the number of heartbeats in a lifetime appears to be genetically predetermined. Water fleas, whose heartbeats can be counted under a microscope, exemplify this phenomenon. At cool temperatures, the fleas' hearts slow down, and the insects live longer. The lifetime total number of heartbeats in fleas kept at low temperatures is almost identical to that in fleas maintained at higher temperatures.

Insects' metabolic rates are also influenced by how much they fly. The reason is that insects use up oxygen about a hundred times faster during flight than they do when they are sitting. How this affects life span may be tested by housing insects in containers of different sizes and, in some experiments, varying the number of insects per container. When 200 male houseflies are crowded into one-cubic-foot cages, for example, they live about sixteen days. When the number of flies per cage is halved, the insects tend to be less agitated by their cagemates and fly less. The average life span of flies under these conditions is twenty days. If the flies are confined to small enough vials, they simply do not fly at all and, on average, live fifty days. When individual flies are placed in small vials and then cooled to 55° F, they seldom move and may last more than six months. Once again, all these different groups of houseflies consumed the same total amount of oxygen.

Exercise may speed up the aging process in insects, but this should not be construed as an excuse to skip a trip to the gym. For humans, a sedentary life style can increase the risk of heart attack and several other fatal diseases. One reason for this striking difference is that mammals can strengthen muscles and other organs simply by using them. Most insects have no such ability. When insects exercise, their tissues are injured by toxic byproducts produced when cells consume oxygen, and the damage is never repaired. The accumulation of damage from physical activity ultimately results in death. Thus, for insects, the tempo of life, not the passage of time, determines how long they live.

The less this housefly—shown here eating some sugar—moves about, the longer it may expect to live. Avril Ramage; Oxford Scientific Films

from accidents. Peter Medawar, the late Nobel Prize-winning immunologist, used an analogy with laboratory test tubes to make this point. Even without aging, no single glass test tube is likely to survive in an active laboratory for very long because scientists are busy and quite often clumsy. However, the probability of a test tube's being broken should not depend on its age. One that has survived one year should be no more likely to break during the next year than a new one fresh out of the carton. (To the extent that the probability of breakage does increase with age, perhaps as a result of increased brittleness or the gradual accumulation of scratches and scrapes, test tubes can be said to age.)

Similarly, an animal's environment constantly presents challenges—such as finding food, avoiding predators, and recovering from diseases—all of which act much as clumsy scientists do on test tubes, as sources of accidental mortality. Animals at their physiological peak will survive these contingencies better than animals that show signs of aging, that is, whose speed, agility, senses, or immune system has begun to decline. This is what makes changes in the mortality rate—namely, the extent to which an animal's probability of death increases as it gets older—such an excellent field measure of aging. Studies have suggested that this measure may be so fundamental to organisms that it is independent of the harshness of the environment within which they live. Gerontologist Caleb Finch and his collaborators have shown that humans, for instance, double their mortality risk about every eight years in environments as widely different as modern industrial society and World War II concentration camps. In the concentration camps, overall death rates were about thirty times higher, yet the probability of dying still doubled with an increase in age of about eight years.

Early field biologists thought that animals probably died in nature from encounters with hungry predators and other "accidents" before much physical deterioration occurred, but this turns out to be untrue, for mammals at least. Jeffrey Peppercorn, a student of mine, and I found that older individuals died at a higher rate in about 90 percent of all wild species studied. Gelada baboons, for instance, double their mortality rate in about three years; Virginia opossums double theirs in about eight months.

Wild birds, in contrast, don't appear to age as obviously in nature. They generally die at about the same rate regardless of their age. Robert Ricklefs, of the University of Pennsylvania, attributes this to the unforgiving demands of flight and likens the mammal–bird comparison to one between automobiles and airplanes. Consider taxis. In Third World countries (and many big cities in the United States), they are frequently in a state of drastic disrepair. Engines howl and smoke, broken lights dangle from bare wire, mufflers drag in the street. Airplanes are rarely seen in a similar state; their penalty for gross disrepair is greater and more immediate. Unlike a professional athlete, a bird that has lost a step (a flap?) is not an overpaid prima donna; it is a dead bird. (Birds do show accelerating mortality in captivity but more slowly than you might expect: tiny species such as canaries can live more than two decades, and parrots occasionally make it to eighty years.)

Aging is, however, detectable in wild birds in the form of declining reproduction. A good example is the great tit, a chickadee-sized bird studied by Christopher Perrins in Wytham Woods near Oxford, England, since 1960. Great tits show no increase in mortality rate until at least the age of seven, but females lay fewer eggs and lay them later in the season after the age of four.

The lives of some species follow yet another trajectory. They live for a while with no signs of aging, then grow old and die very suddenly just after reproducing. Spawning salmon are famous for this sudden aging, but it is also the pattern for octopuses, eels, and males of the shrewlike marsupial *Antechinus stuartii* (see "Marsupial Femmes Fatales," *Natural History,* March 1988).

But why do animals age at all, and even more puzzling, why do different species age at different rates? At last count, there were more than 300 theories concerning how animals age (that is, by what mechanisms), but there are really only two for *why* they age: the rate-of-living and the evolutionary theories of aging. The rate-of-living theory was first put forward by German biologist Max Rubner in 1908 and later named and extended by the American scientist Raymond Pearl. Rubner observed that large mammals, such as zebras or elephants, lived longer than small mammals, such as shrews and mice. Knowing that small mammals have a more rapid metabolic rate per gram of body tissue and that animal cells are basically the same size regardless of the size of the animal, he concluded that each cell of smaller animals must be operating biochemically at a higher speed. Rubner calculated that each mammal species expends about the same total amount of energy per gram in its lifetime and, therefore, that animals with rapid metabolic rates spend their allotted energy rapidly and die young, while animals with slower rates of expenditure live longer. At the same time, a number of researchers noted that if they modulated the metabolic rate of coldblooded animals by cooling them or by reducing their food supply, they often lived longer. A folk version of this idea claims that all mammals have about the same number of heartbeats per lifetime.

On the level of the cell, this idea has a modern incarnation, which assumes that aging is due to the imperfection of biochemical processes. During the normal course of metabolism, some defective proteins will be synthesized, some perfectly formed molecules will be damaged in collisions with other molecules, and cellular waste products may be imperfectly degraded. One intensively studied type of biochemical imperfection is the "free radical," created when normally cohesive electron pairs are broken apart, leaving only a single, unpaired, highly reactive electron. The resultant molecules are so highly reactive that, like bulls in a biochemical china shop, they damage nearly any other kind of mol-

Erwin and Peggy Bauer

Aging

Military macaws, left, may live for many decades, while opossums, below, are lucky if they see year three.

John Shaw; Bruce Coleman, Inc.

ecule they contact—sugars, protein, DNA. Moreover, the damage they cause is self-perpetuating because they also react to create more free radicals.

Another biochemical imperfection has to do with damage caused by chronic exposure to sugar. The simple sugar glucose is the fuel our body runs on. Regardless of what we eat, before our bodies can use a food for energy, it must be converted to glucose. Therefore, we must have a certain level of glucose always available in our cells. But sugar, as we all know, is sticky stuff. In the cell, it has the habit of latching onto enzymes used for other purposes and inactivating them. It can also link important molecules permanently together in a dysfunctional mass. This reaction is the same one that causes the browning of meat on your stove or in your freezer. The problems created by glucose are unavoidable and bad enough, but matters could have been worse. Glucose is the slowest-reacting sugar of its type, least prone to cause this type of damage, and some researchers think that this is why glucose has evolved as the specific sugar our cells use.

The modern version of the rate-of-living theory proposes that ultimately, the accumulation of defective molecules and toxic waste products will cause a decline in cellular efficiency, which, multiplied over millions and millions of cells, results in the general deterioration called aging. The rate-of-living theory holds a powerful intuitive grip on the human mind and is still implicitly held by most of the medical community. But as a way of understanding the wide range of aging rates among animals, and why, in the ultimate sense, aging evolved in the first place, the theory is a failure.

A comparison of birds and mammals can help us see why this is so. It is true that as both birds and mammals become larger, their metabolic rates per unit of tissue decrease and they generally live longer. But for a given body size, birds have a higher body temperature and about twice the metabolic rate of mammals. The rate-of-living theory would predict, then, that birds should be shorter lived than mammals of similar size. In fact, the reverse is true, with birds generally living more than two times as long as similarly sized mammals. Mice and rats, for instance, live three years or so, at the most, in the laboratory, and for perhaps a year maximum in the field. In contrast, the mouse-sized song sparrow has been reported to live more than eleven years in the field. Banding studies have shown that many species of seabirds exceed three decades in the wild (which is about as long as individuals have been marked) and may conceivably live much longer. Thirty- to eighty-year-old mammals in this size range are unheard of.

Even if we stick with mammals, the

rate-of-living theory fails to explain aging rates. Most mammals are either marsupials (pouched mammals, such as opossums, kangaroos, and koalas) or eutherians (most placental species). Marsupials have metabolic rates about 70 to 80 percent that of eutherians. According to the rate-of-living theory, marsupials should thus be longer lived, but the opposite is generally true. For instance, the quoll, a nocturnal, largely insectivorous Australian marsupial, has never lived more than seven years in captivity, whereas Africa's ecologically similar fennec has lived nearly fifteen.

Further complicating matters, there is one group of small mammals—bats—that do live at least as long as comparably sized birds. Don Griffin, an eminent animal ethologist and the discoverer of bat sonar, recalls that once, when he was rechecking one of his bat caves many years after banding a large number of little brown bats, a student assistant looked in amazement at the tiny animal he was holding and exclaimed, "This one is older than I am." There are records of little brown bats living more than thirty years, and the overall mammalian champion in terms of energy production per mass per lifetime is the short-tailed fruit bat, which weighs less than an ounce but has survived more than twelve years in captivity. The exceptional longevity of bats used to be considered a consequence of their habit of turning down their metabolic rate during winter hibernation and even while sleeping in summer—an implicit rate-of-living argument—but tropical bats, which do not hibernate, are just as long-lived. What's going on?

This is where the evolutionary theory of aging comes in. This theory, which I believe provides a general explanation both for aging and for why some species live so much longer than others, is based on the waning power of natural selection as an animal ages. To understand why it wanes, let's go back to Medawar's test tube analogy. Test tubes don't age, but they break nevertheless at a rate dictated by their fragility and the clumsiness of the scientists using them. Imagine that 50 percent

LIFE IN THE SLOW LANE

Lugging a shell around has its rewards, as turtles have known for millions of years

by J. Whitfield Gibbons

An eastern mud turtle and I renewed our acquaintance a few months ago. At our first meeting, in 1967, I captured and marked what looked like a little black rock with legs and then released it into a Carolina bay, the freshwater wetland it calls home. On our recent encounter, within a few feet of where I had released it, it looked the same, no older or younger than before. I don't really know for sure which of us is older, but neither of us will ever see twenty-five again.

Eastern mud turtles are not breathtaking in appearance, but they outdo most other animals in one respect—they live longer. Based on our long-term field studies at the Savannah River Ecology Laboratory in South Carolina, we are sure mud turtles live more than thirty years, estimate many to be more than forty, and believe some are probably more than fifty. Furthermore, in contrast to humans, a five-decade-old mud turtle would probably look and behave just like one half its age.

Turtles hold the documented records for reptile longevity both in the wild and in captivity. Representatives of several turtle families, including snapping turtles, box turtles, and desert tortoises, have survived in captivity for more than half a century. The record is held by a giant tortoise that roamed the grounds of a British fort on the island of Mauritius, until its accidental death (by falling through a gun emplacement) more than 150 years after its initial capture as an adult.

Determining the age of adult turtles in the wild can be difficult. But in the temperate zone, at least, examination of a turtle's shell is revealing, for like the rings on a tree, growth annuli are incorporated into each of the shell plates. In many species of turtles, rings for the first six or seven years of life show up clearly. For some, such as box and Blanding's turtles, fifteen years or more can be counted by examining rings. After that, normal wear and tear often obscures older rings, and as the turtles get larger, new rings are too close together to count.

Older ages can be documented through long-term studies that involve recapturing individuals whose ages were established previously. Such studies have shown unequivocally that a significant proportion of freshwater and terrestrial turtles live for more than a quarter of a century under natural conditions. Several female Blanding's turtles, studied by Justin Congdon on the George Reserve in Michigan, are more than fifty years old. Bruce Brecke and John Moriarty, of the Minnesota County Biological Survey, give an authentic record of one Blanding's turtle known to be at least seventy-seven years old.

Among wild turtles, the risk of dying is low for adults of all ages. For ten-year-old mud turtles, almost 90 out of 100 reach the age of eleven. A twenty-five-year-old individual enjoys the same likelihood of reaching the age of twenty-six. How have turtles managed to evade the perils of predation and natural environmental hazards that plague most animal species? The common denominator among turtles, of course, is the protective shell. The shell insulates its owner against a wide range of temperatures and moisture conditions and, more important, deters most potential enemies. Foxes, opossums, and most other terrestrial predators are likely to lose interest in a meal shut up inside a container that can't be opened. Aquatic predators are also likely to seek more tractable prey than an armored tank

This Blanding's turtle is likely to remain sexu

that has sharp claws and a biting mouth.

The shell appears to be the key that opens the door to longevity in turtles. The protection afforded by the shell endures for a lifetime and may even increase with age. Turtles of many species continue to grow slowly as adults, and as they grow, additional calcium deposition produces thicker and more rigid shells.

But turtles don't just live a long time; even the oldest animals stay fit and reproductively active throughout their lives. Painted turtles lay more eggs at age twenty-five than at age ten. The old matrons in Justin Congdon's Blanding's turtle population continue to lay an average complement of eggs on a regular basis. Here, too, the role of the shell has been crucial. In many animal populations, the death rate mounts with age, the force of natural selection declines, and deleterious mutations accumulate (*see* "On the Nature of Aging," page 24). Thanks to their shell, adult turtles are less vulnerable than many other animals, so the risk of death from external causes does not increase with age. If, as a result of the shell's protection, significant numbers of reproductively active turtles live longer, natural selection can continue to act—through their offspring—weeding out deleterious mutations that cause senescence.

This self-perpetuating process of extending longevity has been going on for a long time. More than 200 million years ago, the earliest ancestors of today's turtles were already armed with shells. Natural selection has thus had ample time to operate against aging in turtles. The result today is a group of animals that apparently retain the qualities of youth into old age. No shell is a match for the automobile, however, nor can turtles withstand the pressures of commercial overexploitation. If these youthful ancients are to continue their march against aging, we faster-paced humans must get out of their way and leave them alone.

Glenn Davis

ve for its entire long life.

are broken each year. After five years, only about 3 percent of the original ones will be "alive"; after ten years, fewer than one in a thousand will still be around. Now imagine that at the age of one year and once a year thereafter, test tubes reproduce like rabbits. Notice that even without aging, most baby test tubes (tubelets?) will have one-year-old parents. Few tubelets will have five-year-olds as parents, and only a minuscule number will have ten-year-old parents.

The evolutionary significance of this logic is that any new mutations that affect only old test tubes can't have much effect, positive or negative, on test tube success in passing on their genes. By contrast, mutations affecting young test tubes will have enormous impact. For instance, a hypothetical mutation that doubled the yearly litter size of ten-year-old test tubes would not be as advantageous as it might sound (that is, would not have much effect on future generations of test tubes) because a test tube has less than a one-in-a-thousand chance of surviving to that age in the first place. At the other extreme, consider a "one-hoss shay" mutation (Oliver Wendell Holmes's poetic carriage that "was built in such a logical way,/It ran a hundred years to a day"), which causes instant death at the age of ten. This mutation wouldn't be much of a disadvantage, since so very few test tubes will live long enough to suffer its effects.

If we considered the same mutations occurring at the age of five, the respective beneficial and detrimental effects would be greater but still relatively minor. However, any mutation that doubles litter size or causes instant death at one or two years of age will dramatically affect the genetic future of those bearing it. Beneficial mutations expressed at this early age will soon predominate in the population, whereas natural selection will soon eliminate early acting "one-hoss shay" mutations.

The power of natural selection thus inevitably wanes as animals grow old, even if they show no obvious signs of aging. The rate at which natural selection declines is

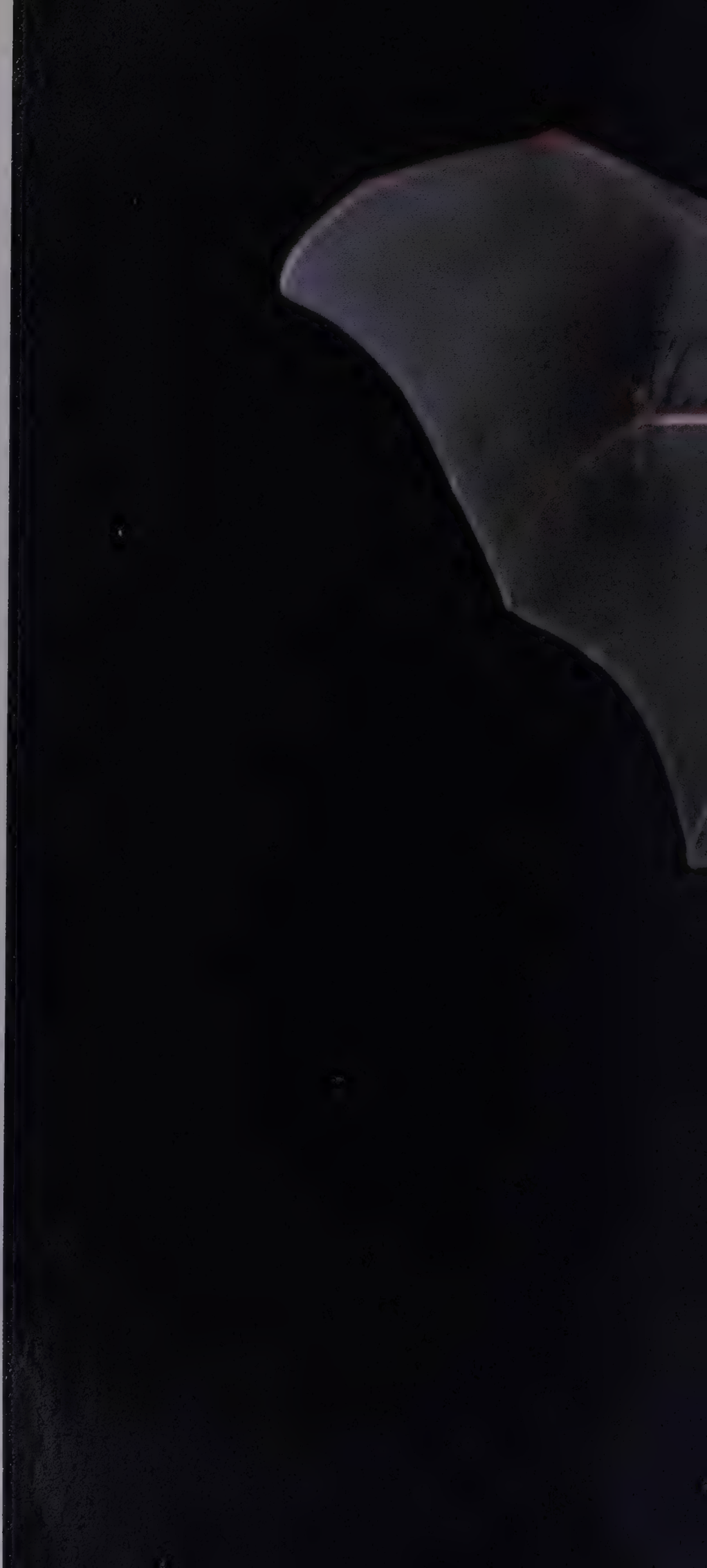
Weighing less than an ounce, short-tailed fruit bats have survived more than twelve years in captivity, making the species the mammalian champion in terms of energy production per mass per lifetime.
Merlin D. Tuttle, Bat Conservation International

variable, however: it will be rapid in a population subject to a high rate of accidental death and slower in a less vulnerable population—one, say, composed of aluminum, rather than glass, test tubes. That is, if only 5 percent of tubes are broken accidentally each year (instead of 50 percent), then after ten years about 60 percent of the tubes will still be "alive" instead of one in a thousand, and therefore a good or bad mutation expressed at this age will still have a substantial impact.

Keeping this logic in mind, we can see how the waning of natural selection leads to the evolution of aging. Since most new mutations are harmful and since mutations with effects late in life tend not to be weeded out, late-acting harmful mutations can accumulate over time. They are virtually immune to elimination by natural selection, which may be why certain diseases, like cancer, occur predominantly in old age.

The evolutionary theory agrees with the rate-of-living theory insofar as they both predict that aging will ultimately come about as a consequence of the gradual failure of physiological or cellular processes. The theories differ, however, in that the rate-of-living hypothesis assumes that the rate of failure is an inescapable consequence of the rate of biochemical processes, whereas the evolutionary theory assumes that the rate of failure may be modified or possibly even halted by natural selection under the appropriate circumstances. This idea doesn't seem unduly far-fetched. There are, after all, known mechanisms for degrading damaging molecules or cellular toxins and resorbing and replacing defective cells. Presumably, natural selection could influence the amount of biochemical resources that organisms put into these damage-defense mechanisms.

Mutations may contribute to the evolution of aging in other ways. Some may, for example, have two effects: one, early and beneficial; the other, late and detrimental. By actively favoring the first, natural selection would automatically bring the second into play as well. This phenomenon,



DIVIDING THEY STAND

Is fission the fountain of youth?

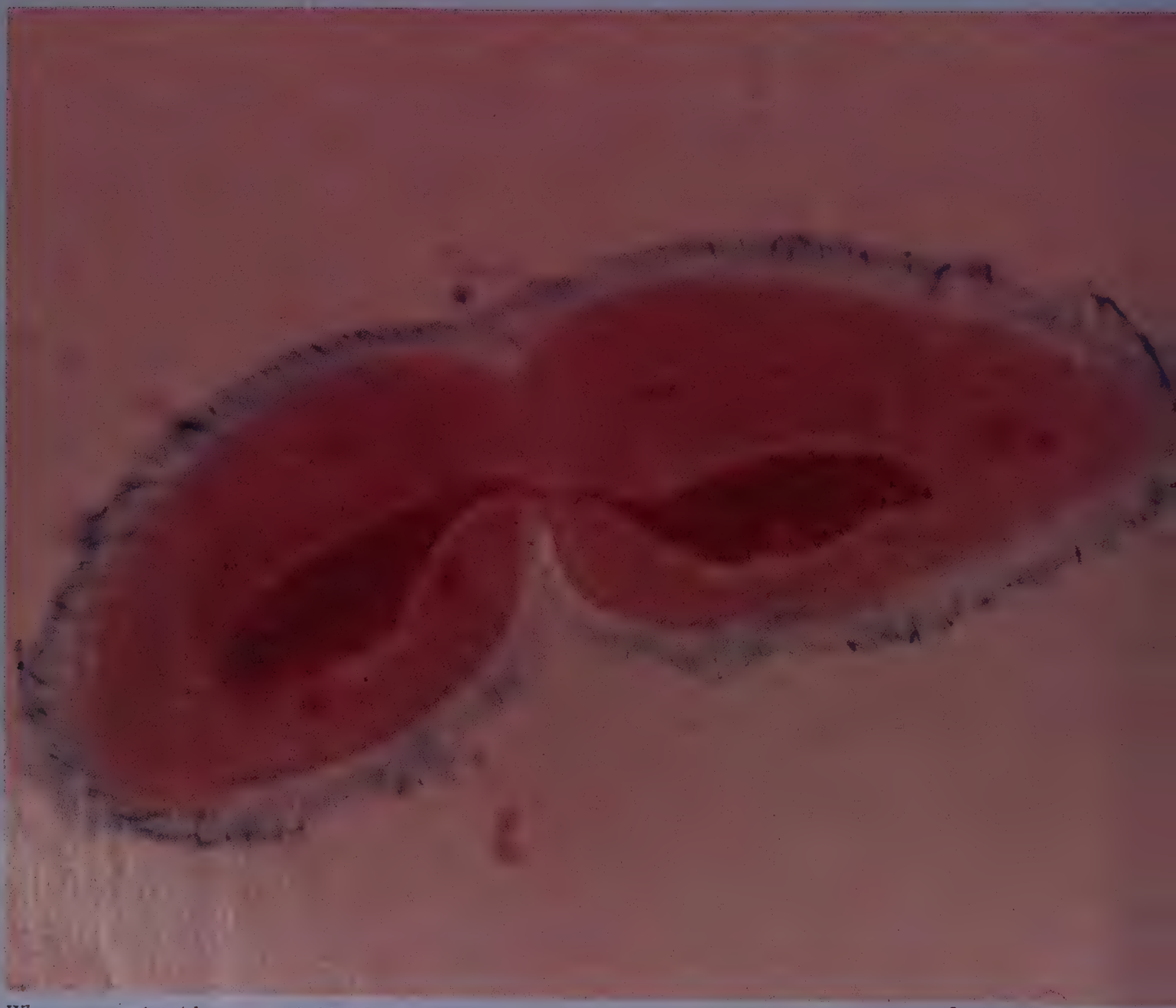
by Graham Bell

The evolutionary theory of aging is intended to explain a common and, when applied personally, disturbing fact of life: the older you are, the greater your risk of dying. The theory was based on large organisms that reproduce by eggs or seeds—organisms like ourselves. But there are many less familiar creatures—such as some worms and sea anemones—that reproduce in a quite different way: by budding off small replicas of themselves or, more simply, by dividing into two perfectly equal halves. Can the theory tell us what to expect in these circumstances? Will such creatures senesce, that is, deteriorate with age?

According to the theory, natural selection favors organisms that spend so much of their resources on producing offspring when they are young that they spend correspondingly little on maintenance; aging is the result. But the products of an equal fission are not parent and offspring; they are two new organisms of the same age. Since there are no "younger" and "older" individuals, there is no way for increased reproduction by younger individuals to be traded off against later survival. The evolutionary theory of aging would predict, therefore, that fissiparous animals do not age.

To test the prediction in the laboratory, I compared the life cycles of freshwater oligochaetes (small fissiparous worms only about a millimeter long, related to earthworms but living in the sediments of ponds and streams) with those of a variety of other freshwater invertebrates, such as water fleas, which reproduce more conventionally, by means of eggs. As expected, the egg-producing forms all showed a marked and regular increase in mortality late in life, even when maintained in optimal conditions. The oligochaetes also died from time to time, but the rate at which they died did not increase with age. As the theory predicts, they seem to be creatures in which senescence is very slow or even entirely lacking.

This laboratory result is consistent with the little we know about the life cycles of similar organisms in the wild. The longest lived of all creatures are not elephants or tortoises or even large trees but colonies of coral polyps or creosote bushes, which can give rise to new units through a process akin to fission and which may live to an age of



When a paramecium (shown magnified 3,000 times) divides, the result is two new organisms of the same age. Bruce Iverson; Visuals Unlimited

thousands or even tens of thousands of years. Here, again, where the distinction between parent and offspring breaks down, there is little senescence, just as the evolutionary theory of aging suggests.

There is one situation, however, that would seem to contradict the theory. Many small, single-celled protozoans can reproduce either sexually or by dividing in two. We might expect that a lineage descending by fission from a single protozoan cell would reproduce with vigor indefinitely, but, as a group of biologists working about the turn of the century discovered, protozoan lineages maintained in the laboratory by single-cell descent gradually grew more and more feeble and eventually died out. Careful work proved that this pattern could not be blamed on any deterioration in the culture media. Rather, some real process of racial senescence—quite different from the aging of individuals—was at work.

Even more dramatically, researchers found that if they crossed the cultures periodically (that is, placed protozoans from different lineages in the same vial, thereby "encouraging" sexual reproduction), the previous steady decline came to a halt, and vigor was restored. Sex supplied the rejuvenating force necessary to restore the fortunes of a declining lineage. How?

Mutations—genetic copying errors—arise continually in all lineages and are almost always harmful. To some extent, natural selection prevents them from accumulating by removing individuals crippled by an unfortunate heritage of mutations, while allowing their more fortunate fellows to proliferate. But selection cannot be very effective in laboratory cultures of protozoans that at any given time consist of fewer than a dozen individuals. The vigor of such populations will slowly fall as the burden of mutations increases, which is where sex comes in. When two individuals mate, their genes are divided in new ways among their progeny: some will inherit more than their share of harmful mutations from both parents and will quickly die; others, having inherited correspondingly few mutations, will be fitter and more vigorous than either parent. In this way, sex acts as a repair device, in somewhat the same way that cannibalizing two broken-down cars might provide spare parts to make one working car.

Sex and death, then, have an unexpected association. Sexual reproduction may allow species such as ours to persist through geologic time despite the corrosive effects of mutation. This may be one reason that all large and complicated organisms indulge in the extraordinary ballet of sexuality. At all events, it adds meaning to the bumper-sticker claim that Life Is a Sexually Transmitted Disease.

which is basically a trade-off of early gains for later losses, is known by the tongue-twisting term "negative pleiotropy," and its relevance to aging was first pointed out in the 1950s by George C. Williams, of the State University of New York at Stonybrook. In our population of hypothetical test tubes, a mutation that doubled litter size at age one, but at the same time doubled the death rate in every year thereafter, would spread quickly throughout a population.

A variety of genes are known to have multiple effects. One example is the gene that causes sickle cell anemia, which also happens to protect carriers against some kinds of malaria. As a possible example of age-related negative pleiotropy, Williams speculated that genes that enhanced early survival by promoting bone hardening during development might reduce later survival by promoting arterial hardening. Recently, he has cautioned that before we fiddle with genes known to cause common problems of old age, such as certain types of Alzheimer's disease, we ought to consider that these genes may be associated with some benefits early in life.

Do such trade-offs exist? If so, might they be an important key to understanding the physiological mechanisms of aging? One way to examine this question is to experimentally alter, in the laboratory, how much and when an animal reproduces and then see what effect this has on life span. Female lab mice kept from breeding, for instance, outlive reproductively active females by as much as 100 days. Male antechinus, which usually die abruptly after breeding, live on nicely if kept apart from females. Even annual plants remain alive for years if their flower buds are cut off as they appear. And part of veterinary conventional wisdom is that the oldest patients are the spayed and neutered ones.

One current puzzle in biomedical studies of aging, and one that may be relevant to the role of reproduction, is why dieting retards aging and extends life in rats and mice. If you reduce the food intake of these rodents by 30 to 40 percent and give them sufficient vitamins and minerals, they will live as much as 50 percent longer. They not only live longer but also stay younger longer. Many measures of physiological performance confirm this rodent fountain of youth. Significantly, one effect of this dietary restriction is that if started before puberty, it delays sexual maturity; thereafter, it curtails reproduction. Therein may lie the tale, and we may learn a great deal about the mechanisms of aging by studying these dieting mice. (At any rate, it is a topic I find particularly comforting since I spent a good deal of my youth on the strict dieting required of schoolboy wrestlers.)

In the laboratory, scientists have used artificial selection to produce long-lived strains of both fruit flies and soil-dwelling roundworms. In these cases, too, long-lived strains reproduce less.

Does this evolutionary theory of aging suggest anything about the exceptional longevity of birds and bats or the abrupt senescence of eels and salmon? Remember that the rate at which natural selection wanes is determined by an animal's environmental accident rate. Could it be that birds and bats, because they fly, are resistant to certain sorts of accidents? After all, flight may be physically demanding, but it is a superbly effective way to escape predators.

If flight renders birds and bats less vulnerable to predation, then another group of mammals, which I call the aerial sailors, might experience a similar benefit. More than fifty species combine nocturnal, arboreal habits with flight of a sort, gliding from tree to tree. They range in size from a few ounces to more than two pounds and include some American, African, and Asian squirrels, several families of marsupials, and a small group called colugos, or flying "lemurs." Little is known about most of these species, but the ones about which we have reliable information are considerably longer lived than expected for mammals their size. The common flying squirrel of the eastern

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To Bee Young Again

Honey bee homebodies live longer

by Gene E. Robinson

"Bees don't get older, they get better!" exclaimed a colleague of mine, upon learning that adult worker bees perform what is probably their most difficult task—food collection—only later in life. Foragers must learn how to navigate via landmarks and celestial cues, as well as how and when to obtain nectar and pollen efficiently from several different plants, all blooming at the same time. Then they coordinate their foraging efforts and communicate with one another through a sophisticated "language" of dance.

Foraging is also the bees' riskiest and most exhausting occupation. Away from the relatively safe confines of the nest for about ten foraging trips per day, bees risk being eaten by a host of predators: other insects, spiders, birds, and small mammals. Even if they manage to avoid predators, foraging bees age rapidly. According to research conducted by biologist Angelika Neukirch of Würzburg, Germany, bees simply wear out after approximately 500 miles of flight, because of a failure in the enzymatic machinery powering their flight muscles. So consuming is foraging that honey bees rarely live for more than a week or two after entering this phase of their lives. In contrast, bees apparently age more slowly during the period of nest activity that precedes foraging. This phase, devoted primarily to brood rearing, comb construction, nest maintenance, and food processing, usually lasts for about three weeks but may continue for several months during inclement weather.

Postponing foraging—with its associated wear and tear—until later in life may have evolved because a worker's reproductive potential declines as she ages (all workers are females), suggests entomologist Mary Jane West-Eberhard of Costa Rica. This idea arose because some workers in more primitive societies reproduce routinely, while honey bee workers are effectively sterile under normal conditions. (A honey bee colony typically consists of reproductively active bees—a single long-lived queen and anywhere from no male drones to several thousand—and tens of thousands of workers that perform all tasks related to colony maintenance and growth.) Alternatively, entomologist Robert Jeanne, of the University of Wisconsin, has proposed that delayed foraging evolved because colonies composed of long-lived workers would be more successful than those with short-lived members. According to this view, the intertwined processes of behavioral development and aging, like other morphological and behavioral characteristics of individual colony members, have been molded by natural selection to increase colony fitness.

Delayed foraging results in an age-based division of labor among workers that is fundamental to the efficient organization of large insect societies, such as the honey bee's. Although workers do generally labor in the nest when young and forage when they become older, little appears to be written in stone. Bees can accelerate, retard, or even reverse their behavioral development in response to changing environmental conditions. For example, a surge in worker birthrates, due perhaps to favorable environmental conditions in late spring, may result in a colony that is deficient in foragers. Under these circumstances, young bees can dramatically compress their period of nest work, from three weeks to one week,

This honey bee, its bulging pollen baskets proof of its foraging success, probably has less than

and become "precocious foragers." In a new colony founded by a swarm (a portion of an old colony that has left to establish a new one), there are plenty of older individuals but few young ones, and some colony members retard their development and serve as overaged nurses for the all-important new generation. Behavioral reversion, from foraging to nursing, has not yet been observed under natural conditions but can be induced by depleting a colony of all workers except foragers. Bees then become younger, both behaviorally and physiologically. For example, glands that once produced food for larvae, but that have since degenerated or shifted to producing other substances, become capable once again of producing brood food.

My colleagues and I have begun to study the mechanisms that underlie a bee's capacity to alter its behavioral development. We, and others, have discovered that juvenile hormone (one of the most important hormones influencing insect development) acts as a behavioral pacemaker in honey bees. Indirect evidence of the hormone's role is its low level in young bees working in the nest, compared with higher levels in older foragers. Direct proof has also been obtained: young bees given hormone treatments become precocious foragers.

Manipulating hormone levels on a bee-by-bee basis is one thing; demonstrating that the bees alter hormone levels themselves in response to changing conditions is another. To do this, Robert Page, Colette and Alain Strambi, and I induced precocious foraging by establishing colonies that consisted initially of only very young bees. Then we tested for blood levels of juvenile hormone and found that week-old precocious foragers had levels that were higher than those of week-old nurses and about the same as those of three-week-old foragers. Two weeks later, we obtained overaged nurses from these colonies by removing all pupae that were ready to emerge: hormonally, these old nurses resembled young nurses, rather than foragers. From work with other experimental colonies, we found that bees that reverted from foraging to nursing were also young, hormonally.

Plasticity in behavioral development is also influenced by genetic factors. Using colonies composed of workers with identifiable genotypes, we learned that workers of some genotypes were more likely to forage precociously, while workers of other genotypes were more apt to develop into overaged nurses. Perhaps colony members differ genetically in how sensitive they are, hormonally, to environmental change. Or, alternatively, rates of behavioral development may differ genetically, and these differences may be accentuated under stressful conditions.

Honey bee colonies are dynamic entities that must constantly cope with changes in population size and structure, food availability, predation, and weather. They would be ill-served by an inflexible division of labor. Instead, workers have evolved a remarkable plasticity in their responses to the needs of the colony. As a result, a worker's chronological age is a less reliable indicator of its function in honey bee society than is its state of behavioral development. Or, as my colleague William Greenough was moved to write after hearing me lecture on this topic:

> They say life as a bee is ideal
> For despite a caste system quite real,
> Since a hormone defines
> The societal lines,
> You're only as old as you feel.

K. G. Preston-Mafham; Premaphotos Wildlife

two weeks left to live.

Clams, such as this member of the Tridacna *genus of giant clams, reveal their age in annual growth rings; some appear to be more than two hundred years old.*
Ron and Valerie Taylor; Bruce Coleman, Inc.

United States, for instance, is about the size of a chipmunk but has been reported to live as long as seventeen years in captivity, compared with a chipmunk's eight. I suspect that as more research is done on these aerial sailors, they will prove to enjoy relatively "safe" lives.

Similar exceptional longevity is found in other groups of mammals with special protection of some sort: tree dwelling, for example, or spines, as in porcupines, anteaters, and hedgehogs. Similarly, some of the longest-lived animals known are well-protected turtles. Note that this longevity is due not simply to current increased safety but to an evolutionary history of increased safety, which may have given the species time to evolve special physiological protective mechanisms against the ravages of free radical and glucose damage.

A similar logic might be used to explain why Pacific salmon age so suddenly after reproducing. After migrating to the ocean to live for a number of years, these salmon return to spawn in the freshwater streams in which they were born. Thanks to television, we have all seen their arduous and dangerous return trips. The dangers inherent in migrating to the sea and returning may be so great that the probability of doing it twice is minuscule. Therefore, evolution may favor one huge, exhausting burst of reproduction.

An excellent species for studying the relationship between migratory dangers and aging might be the American shad, which like the salmon is born and spawns in the same freshwater stream and in between lives a peripatetic ocean life. What is interesting about the shad is that fish that spawn on the east coast of North America south of about Savannah, Georgia, all die after reproducing once, but as one heads to streams farther north, more and more shad reproduce repeatedly. In southern Canada, some may reproduce up to seven times. Furthermore, fish in the southern populations produce three to five times the number of eggs per pound of body weight than do those in the north.

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WANT A LONG LIFE?

Get a few good pairs of Mhc genes

by Caleb Ellicott Finch

The odds of living a long time are always poor for wild animals. Dangers abound from the moment of birth. Even in captivity, some species are doomed to shorter lives than others, regardless of danger. A mouse or rat has a maximum of only a few years of life even in the best laboratory environment or pet owner's cage, while cattle and horses can live to about forty years, which is, in turn, half the human life expectancy in many parts of the world. No one doubts that these huge disparities are determined by genes, and new clues about the nature of genes that control life span are beginning to tell us how.

The first chapter in this futuristic tale was written by Roy Walford, who recently entered the Biosphere II "space station" in the Arizona desert. In his more earthly life as a pioneering gerontologist, Walford studied whether genes of the immune system influenced life span. He focused on the genes that control the acceptance or rejection of skin grafts in mice. These genes, and their counterparts in humans, are studied intensively to improve the success of organ transplants in humans, so a great deal is known about their molecular biology.

About fifty in number, these genes, clustered on chromosome 17 in mice and its equivalent in other vertebrates, are known as the major histocompatibility locus, or Mhc. All genes have variant forms, or alleles. Interestingly, the genes in the Mhc show an unusually large number of allelic variations from individual to individual.

Walford and his colleagues showed that mice with different Mhc allele combinations also differed in their life spans and in the rates of aging of their immune system. These studies were the first to point out a group of genes with a known function and link them to life span. Given the scope of the genetics–life span problem—there are at least 50,000 genes in mice and men and the Mhc genes are less than 0.1 percent of the whole set—Walford's contribution is considerable. Maybe he handed us the needle in the haystack.

My interest in the Mhc began when Walford suggested that I look into the reproductive aging of mice with differing life spans. For some years, my laboratory has studied reproductive aging for several reasons. We hope to learn the causes of menopause and also of Down's syndrome and other congenital defects that become more frequent in children of mothers approaching menopause. I am also interested in the role of genes in determining how long an organism can reproduce—because in all species, each generation is subjected to natural selection for genes that allow the reproductive period of life to last long enough for the population to be stable in size.

Evolutionary biologists speak of the reproductive schedule, by which they mean a set of traits that determine the onset of sexual reproduction, the frequency of births, the number of fetal deaths and abnormalities, and how long reproduction continues. These traits are thought to be genetically selected for in response to shifting dangers in the environment. For example, if an increasing number of predators suddenly start attacking adult mice, natural selection should favor individual mice that reproduce earlier in life and that have more offspring each pregnancy.

The reproductive schedule is thus closely intertwined with life span potential and is, I think, a fundamental factor in determining the life span itself. Looking at the Mhc with this thought in mind, my colleagues and I turned up some surprising features of this gene complex. Steve Lerner, then a postdoctoral student in my lab, found that mice with differing life spans had parallel differences in their reproductive schedules, with the longest-lived genotypes reproducing to the latest age. Moreover, the frequency of fertility cycles in young mice was influenced by the particular set of Mhc alleles they carried.

We then combed scientific journals for other connections between Mhc and reproduction and discovered that researchers elsewhere had demonstrated that some Mhc variants influence the response of mice

Any racehorse that runs fast and then enjoys a long retirement at stud must have a winning

to hormones, including insulin and glucagon. These and other metabolic hormones are important to the storage of resources for nursing and surviving when food is scarce. Particular Mhc alleles also affect how strongly the immune system responds to specific antigens, such as viruses and parasites. Thus the Mhc has the capacity to influence many different physiological systems that bear directly on the potential for effective reproduction.

The mechanisms by which the Mhc affects the endocrine system are partly understood and involve close interactions of proteins coded for by Mhc genes with the proteins of hormone receptors. Subtle differences in the structure of Mhc proteins nudge their neighboring receptor molecules to act in a certain way when presented with a hormonal signal. The strength of this nudging is influenced by particular Mhc alleles. This type of mechanism is also thought to influence the strength of responses to foreign antigens, including those that occur during the sorts of tissue transplants that led to the discovery of the Mhc.

Commercial breeding of horses, chickens, and other domestic animals illustrates how closely the Mhc genes influence reproduction. Breeding efforts, for instance, can be directed at improving such traits as number of offspring, milk and egg production, and the age at first reproduction. In many cases, different breeding lines—say, hens that lay well versus those that do not—proved to have different alleles of Mhc genes. In other words, breeding, which is artificial selection for certain traits, can cause the frequency of certain Mhc variants to change, even though the selection process was not explicitly based on knowledge of the gene forms involved.

These various findings, taken together, led Lerner and me to develop the hypothesis that the Mhc has had a longstanding role in life history evolution. The story must end here for now, since the kinds of genetic experiments that allow resolution of the roles of the Mhc in mice are not possible in humans. The long human life span and the decades-long reproductive schedule could involve many genes besides those in the Mhc. Much more work remains to be done, but the information gathered so far about the diverse roles of the Mhc points to a new avenue of research on the genetic basis of evolutionary changes in life span.

William Strode

ombination of alleles.

Aging

Moving through pansies like a tiny armored tank, this eastern box turtle has little to fear from predators.
Glenn Davis

Nothing is yet known about the relative dangers of migration in these various populations, but it is tempting to suggest that fish in the south face more hazards.

If the explanation of slowed aging due to an evolutionary history of reduced vulnerability to predators or other "accidents" is correct, one ought to be able to locate isolated populations that have had a major source of mortality removed and that consequently exhibit slower aging. This is exactly the research tack I have taken with the Virginia opossum.

A number of years ago, while studying a South American species of opossum, Mel Sunquist, of the University of Florida, and I were struck by the rapid deterioration we found in some of our older female study animals. For an opossum, "older" means two or three years of age. We would capture an animal in seemingly perfect health and recapture her a few months later only to find she had developed cataracts and become doddering and disoriented. Although we weren't particularly interested in animal aging at the time, I continued to be bothered by why this animal, which is about the size of a small house cat, should age so much more rapidly than any cat I'd ever heard of.

I finally became convinced that the opossum's special vulnerability to predation might lie at the heart of the matter. Opossums are slow moving and virtually defenseless against a wide variety of predators, from domestic pets to coyotes, owls, and bobcats, not to mention cars. In some parts of the South, the roads are fairly carpeted in the spring with possum pancakes.

In evolutionary terms, these animals should find it advantageous to reproduce early and often, even at the cost of premature aging, because otherwise they are likely to be killed before leaving any offspring. In fact, opossums do reproduce early and often compared with other, ecologically similar mammals, such as raccoons. Opossums can breed at six to eight months and generally have two litters of

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LEADING LADIES

In baboon society, elderly females often call the shots

by Jeanne Altmann

As her young infant alternately suckled and dozed in the shelter of her lap, the elderly baboon, known to us as Handle, stared intently toward the distant grove of trees. The five dozen members of her group sat tensely in clusters nearby. Indecision was in the air, and even the playful juveniles seemed to sense it, staying closer to their older relatives than they had all day. A short while before, as they were heading southward toward a grove of trees in which to spend the night, the group had spotted a leopard—the baboons' major predator. Although the leopard was no longer visible, the chatter of vervet monkeys in the distance, near the intended sleeping trees, confirmed that danger would await the baboons if they continued as planned. The sun was dropping rapidly now, and the short equatorial dusk would give the baboons little time to make a decision: stick to the original plan or strike out for one of the other groves—all farther away—scattered across their East African savanna home. If they didn't act fast, darkness would overtake them far from the safety of tall trees.

Occasionally, one young adult or another gave rapid, soft vocalizations and started moving tentatively toward the original grove or in another direction, but the other baboons remained in place and the initiator soon sat again. After ten long minutes, in a single, smooth motion, Handle stood, her infant still clutching her sides but now riding under her, and began to move decisively westward toward a grove still hidden in the dusty, dry-season haze. Barely a few seconds later, her daughter Heko followed with her own infant on her back. Handle paused as she looked back; throughout the group, baboons responded with soft grunts and moved to follow her. The rippling motion rapidly grew into a wave, and soon, all the baboons followed, silent except for the protests of tired youngsters for whom first the tension and now the sudden rapid pace were too much. By the time the baboons reached the grove, the light was nearly gone, and the animals were little more than silhouettes as they ascended the trees. I just barely made out Handle as, hunched stiffly over her sleeping infant, she settled onto a comfortable branch for the night.

During more than twenty years observing baboons in Amboseli National Park in southern Kenya, my colleagues and I have seen one elderly female after another serve as leaders at critical times in group movements. Actual fights with predators or other baboon groups usually involve many troop members; then, adult males are often in the fore, but each animal seems to know or decide for itself whether to flee, hang back, or threaten the intruders. In contrast, the decisive role of elderly females more often is seen at "controversial" moments in group movements, when all will take the same route, but just which route is not clear or agreed upon. At those times, elderly females (those over about fifteen years of age) seem to make the choices that are followed. We don't know for sure why the "opinions" of these females carry so much weight. Social rank is not the answer, for we have seen high-, low-, and mid-ranking individuals (such as Handle) lead the group. The permanent members of baboon society are the females, and many older females tend to have several daughters and other descendants in the group. Could the most influential females simply have the most descendants? Certain evidence seems to support this. Like Handle, elderly Alto had many offspring and she, too, was a leader at times. In contrast, we have never observed eighteen-year-old Dotty, who has few offspring, or Dotty's age-mate Janet, who has none, assume leadership roles.

The equation cannot be a simple one, however, for another elderly female, low-ranking Este, had few offspring and yet was often a leader at critical junctures in the troop's life. Perhaps the explanation lies in the extent to which the leaders are enmeshed in a longstanding, complex network of social relationships. Unlike males, who change group membership when they mature, females spend their whole lives in the

When uncertain about which way to go, a group of savanna baboons is likely to follow the lead

group in which they are born. Certainly, twenty-three-year-old Handle has had a long time to build up a social network. Although none of her elders and few of her peers are still alive, all of the group's youngsters have grown up knowing her.

Few baboons live long enough to develop the kind of rich social network Handle enjoys. Less than half the baboons in the population survive infancy, and once they reach adulthood (at age six for females and eight for males) the annual death rate is about 10 percent. The rare elderly survivors like Handle usually seem somewhat slow and stiff. They sometimes drop to the rear of the group, especially in the morning cold, as the baboons set off for the day's six-mile foraging trek, and in the late afternoon, when the fatigued animals move to a sleeping grove. Although Handle actually still seems fairly spry, her teeth are very worn, and her weight seems to have declined in recent years, suggesting that she may need to spend more time feeding to obtain enough digestible food.

Not surprisingly, perhaps, Handle, like other elderly females, often seems to be somewhat separate from younger members of the group and to have less time to interact with them. And yet she is undeniably an active group member. Several factors of baboon life help keep it that way. Baboon females continue to bear young throughout their lives (although slightly less frequently), and when infants are born, relatives, friends, and just plain curious acquaintances cluster about the infant and its mother. Motherhood is a way of renewing and reinforcing social ties. These ties are further cemented by grooming, the baboons' way of keeping in close touch—calming one another down, sharing messages. Females groom their grown daughters, special unrelated male friends, and others in the troop. We think it significant that Handle has long been one of the group's most frequent, and most thorough, groomers.

Carol D. Saunders

ld female.

The life of male baboons follows quite a different path. Even as two- or three-year-olds, they begin to move away from their mothers' world. Young females increasingly reciprocate their mothers' grooming; young males do not, and their mothers soon discontinue grooming them. In addition, the young males' social interactions involve more partners outside their maternal lineage, so that by the time males leave their birth group, at eight or nine years of age, they have experienced a broader range of social relationships than have their female peers. This is probably of great value, considering the tasks they face: those males that survive to immigrate into another group must deal with a hostile reception by the resident males. They must also develop all new relationships with both males and females, including potential sexual partners. And unlike females (who inherit their mother's social rank and retain it throughout adulthood), males must compete for the rank they attain and cannot expect to keep it: for males, status peaks in young adulthood and declines more or less rapidly soon thereafter. Social relationships may change even more for those males who, like Handle's firstborn son, Hans, switch groups several times. Moreover, males do much less grooming than females and, at least as young adults, do so primarily with potential sexual partners.

For all these reasons, we might expect to find that aging males are less socially integrated and have fewer social resources. However, studies increasingly document long-term friendships, involving grooming and some infant care, between mature males and females. Sometimes older males in these relationships have even greater success sexually than do dominant, younger males. Newly weaned youngsters may also benefit from the protective friendship of older males, who occasionally perform acts of heroism—defending the youngsters from injury by other adult males or rescuing and carrying them to safety when they cannot keep up with the group's rapid flight from predators.

Reaching old age may be rare in savanna baboon society, but those individuals that do survive are much more than decrepit hangers-on. As fellow primates, they suggest some of the many ways of growing old and contributing to a complex social world.

WISE, AND OTHERWISE

Our mental hardware declines with age, but our software sometimes improves

by Paul B. Baltes

Biologists tend to treat aging, almost by definition, as a phenomenon of decline. But the course of a human life is more than just the inevitable outcome of biology. Human development, and thus aging as a part of this process, reflects the influence of two streams of inheritance: genetic and cultural. Two human accomplishments illustrate this: the ability of most of us to read and write and the tremendous increase in longevity witnessed during this century as a result of better medicine and more healthful life styles. Our genes provide the potential for both accomplishments, but neither would have been possible without the cumulative gains of human culture.

During the last decade, at Berlin's Max Planck Institute for Human Development, my colleagues (especially Reinhold Kliegl, Jacqui Smith, and Ursula Staudinger) and I have been studying the gains and losses of the aging mind. We distinguish between two major types of intellectual function: mechanics (information processing) and pragmatics (factual knowledge and problem solving). We argue that biological conditions reign supreme in the mechanics of the mind and that decline with aging is therefore likely. In the area of cognitive pragmatics, however, the power of culture unfolds, offering at least the possibility of gains with age.

To use a computer term, the cognitive mechanics are the "hardware" of the mind—the input of sensory information, visual and motor memory, and simple processes of discrimination and categorization. How quickly and accurately, for example, can we make distinctions between colors or geometric forms? How well do we remember simple visual or auditory stimuli?

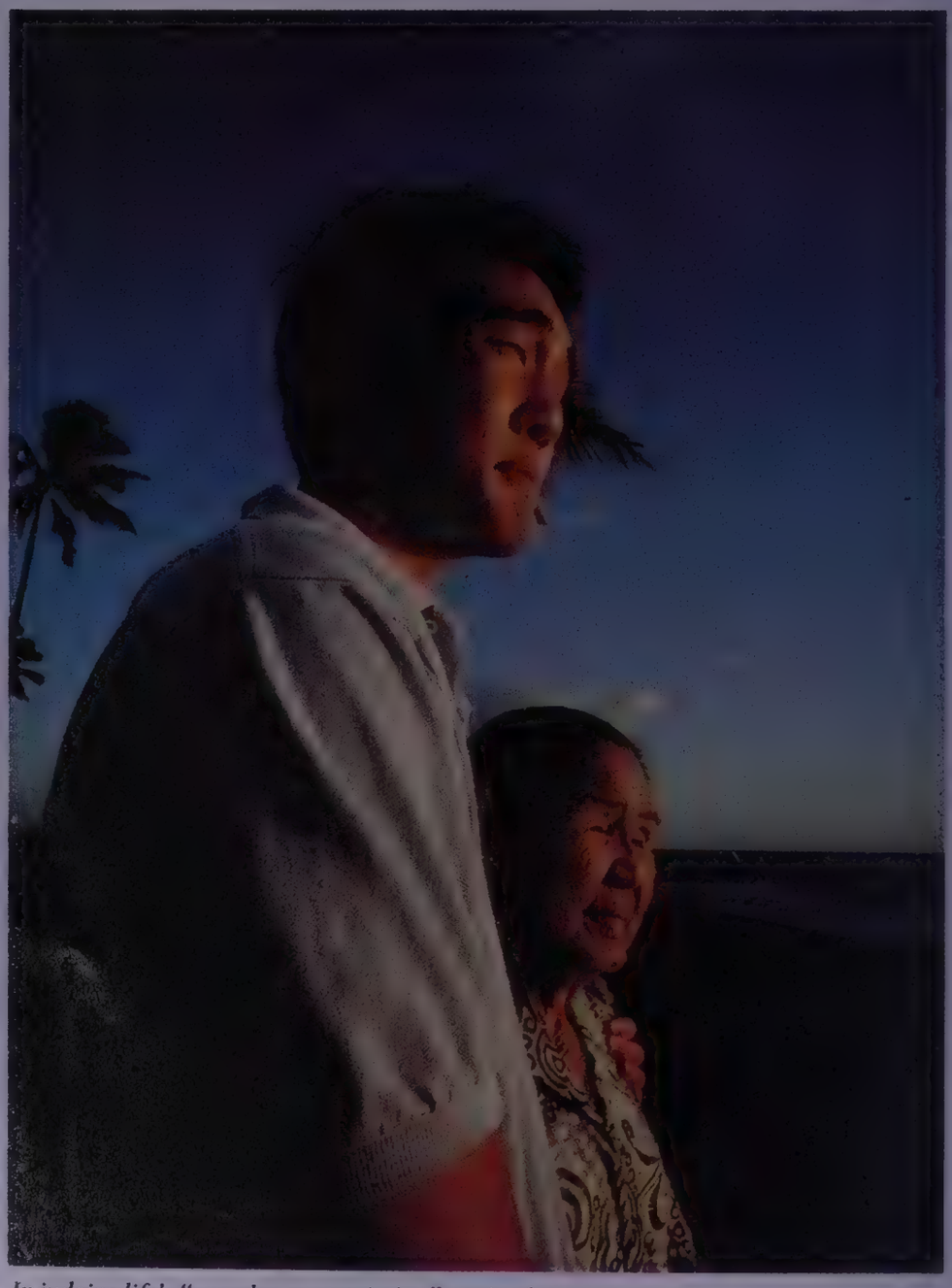
To measure how mental hardware may deteriorate with age, we test basic memory skills of young and older adults. We ask participants in our research to memorize a long list of words, say, thirty nouns: car, plane, house, chair, and so on. To make the task more difficult, we require that they remember not only the words, but also the order in which they were given.

When words are presented once at a speed of about two seconds per word, most of us can remember a string of five to seven words without the help of a memory technique. Remembering longer lists is possible, however, with the help of a memory strategy known since ancient times: the method of loci. To use this technique, you first learn a fixed list of places, such as the Eiffel Tower, the Berlin Wall, the Louvre, the Great Wall of China, the Golden Gate Bridge. You need as many places as there are words to remember. Once acquired, the list is a kind of mental map that can be used time and time again.

The next step is to form a mental picture, connecting each word on the list with one of the locations. For example, if the first word were car and the first place on your list of locations were Eiffel Tower, you might come up with a mental picture of a Mercedes dangling from the top of the Eiffel Tower. Then you move on to the next word and connect it visually with the next place on your mental map. Later, when asked to recall the entire list of words, you revisit the locations, one by one, retrieve the mental picture for each place, and decode it into the word to be remembered. With enough practice, you can remember long lists of words this way, and all in the correct order. Some people reach into the hundreds.

Because the mental operations required by the method of loci are part of the mind's basic biological hardware, we expected that acquiring and using the method should be fairly simple. And indeed, this is so. Almost anyone can learn the method of loci and, after just a few practice sessions, be pretty good at it.

But what about performance in old age? A typical seventy-year-old, we learned, takes three to four times as long as someone in her twenties to find and remember a mental picture linking word and location. Older adults also make more mistakes. And most important, the losses with age seem to be irreversible. Even after forty hour-long



In judging life's "complex uncertainties," age is often an asset.
Eikoh Hosoe

training sessions, seventy-year-olds cannot do as well as young adults do after only a couple of sessions. To date, despite much effort, we have been unable to find a single person over seventy who could compete in the top range with younger adults. When it comes to such biologically based mental mechanics, then, old age takes an undeniable toll.

The situation is entirely different, however, when we look at the kind of knowledge that is transmitted from generation to generation through culture. This is where cognitive pragmatics, the second major type of intellectual function, comes into play. Cognitive pragmatics is—to use another computer term—the "software" of the mind. Examples include such acquired skills as reading, writing, and language comprehension, as well as knowledge about how to handle life's ups and downs.

We could not, of course, test how aging affects all such mental software. We needed a paradigm, some illuminating example of an area of cognition that would clearly show the putative benefits of growing old. After much thought, we decided on that ancient dream of excellence, wisdom, which we defined as expert knowledge about life in general and good judgment about how to conduct oneseif in the face of complex, uncertain circumstances.

To test for wisdom, we present people in our laboratory with difficult hypothetical dilemmas. One might be: Imagine that a friend is about to call to tell you that she can't go on anymore and has decided to commit suicide. How would you handle this situation? Or a fifteen-year-old girl tells you she is thinking about getting married right away. What might you tell her to consider? We then ask our research participants what kind of knowledge they would bring to bear on the issues.

The responses we get to these and other dilemmas vary widely, and over the years, we have developed a "wisdom scale" on which we place the answers. Take the problem of the fifteen-year-old girl. A participant might respond: "A fifteen-year-old girl wants to get married? No, no way, marrying at age fifteen would be utterly wrong." Even after further cuing about possible extenuating or modulating circumstances, this person continues to insist that the problem is a simple one with one answer: "Marriage is not possible."

Another answer might reflect a deeper knowledge of the human condition: "Well, on the surface, this seems like an easy problem. On average, marriage for fifteen-year-old girls is not a good thing. Thinking about getting married, on the other hand, is not the same as actually doing it. I guess many girls might think about it without getting married in the end. And then, there are situations where the average case doesn't fit. Perhaps in this instance, special life circumstances are involved, such as, for example, the girl having a terminal illness or being all alone in the world. Or as I think more about it, this fifteen-year-old girl may not be from this country in the first place; perhaps she lives in another culture or even historical period where girls marry early. . . . Before I could offer a final evaluation or even give advice, I would need to have more information."

To us, the second reply demonstrates more of the culturally and experientially accumulated knowledge that we define as wisdom: rich knowledge of the course and variations of the human condition, an appreciation of the complexity and cultural variability of life circumstances, and recognition of the relativity of values and priorities. It also demonstrates a good sense of the uncertainties of life—that any life situation has a particular balance of gains and losses—and in addition, it reflects empathy and an interest in the well-being of others.

Our results have been dramatically different from those on the mechanics of memory. Older adults have received some of the very best scores in our "tests" of wisdom. Not all older adults are wise, of course, but in our work so far, more than half of the top responses come from people above sixty years of age. And the longer our research goes on, the more we have come to think that someone in the last season of life may well hold the "world record" in wisdom.

One of the most positive effects of culture, then, might come with age. Knowledge about the conduct and meaning of life accumulates with the passing years and, under favorable conditions, is organized in ways that can make it something very special: what we call wisdom. Moreover, this special body of knowledge can be powerful enough to compensate, at least in part, for biological losses. In some cases, culture may almost "outwit" biological limits. When Artur Rubinstein was asked in a television interview how he managed to remain such a successful concert pianist in his old age, he mentioned three strategies that exemplify wisdom: perform fewer pieces, practice each piece more frequently, and—to compensate for a loss in mechanical speed of playing—introduce more ritardandos before fast segments so that the playing speed sounds faster than it is in reality.

In tasks requiring professional expertise and wisdom, then, progress is possible even into ripe old age. For me, this is cause for optimism. Only during the last century have so many people reached old age. With more and more people living longer, and thus—at least potentially—growing wiser and wiser, who's to say what the aging mind may contribute to the future?

seven to eight pups (occasionally as many as thirteen) per year. By comparison, raccoons don't begin to breed until they're one or two and usually have just one litter a year, of two to five pups. And raccoons may live up to sixteen years in the wild.

A few years ago, I began looking for an opossum population that had been sheltered from at least some of its predators for a long time. I located a site that seemed appropriate: Sapelo Island, Georgia. Sapelo, formerly owned by tobacco magnate R. J. Reynolds and now a Georgia State Wildlife Refuge, is an enchanting area dominated by tall pines and magnificently gnarled live oaks festooned with Spanish moss. The island has been separated from the mainland by about five miles of water, farther than opossums are likely to swim, for about four millennia, or several thousand generations of opossums—plenty of time for the island opossums to evolve separately from their mainland relatives. Sapelo Island lacks all mammalian predators of opossums. As a result, opossums often wander about during the day and sleep essentially in the open. (On the mainland, they are nocturnal, spending the day in deep underground dens.)

To my satisfaction, the absence of predators has affected more than just the opossums' behavior: opossums age more slowly on Sapelo than they do on the mainland, just as the evolutionary theory of aging would predict. The oldest radio-collared individual I've monitored on the island is more than a year older than any I've tracked on the mainland at my study site near the Savannah River Ecology Laboratory in Aiken, South Carolina. And whereas less than a quarter of the females live into a second reproductive year on the mainland, half do so on the island. In addition, the mortality rate doubles every eight months on the mainland but takes more than a year to do so on the island.

The populations also differ with respect to reproductive aging. Those few mainland females that make it to a second breeding year have slower-growing young and are more likely to be infertile than

Like most little birds, this great tit from Asia may live at least twice as long as most comparably sized mammals.
Toshiaki Ida; Nature Production

they were the year before. For island opossums, this is not so. And just as longer-lived species of mammals tend to bear fewer young at a time than do short-lived species, opossum litters are smaller on Sapelo than on the mainland: about five per litter instead of seven or more. Donna Holmes, a postdoctoral associate, and I are currently rearing opossums from both populations in a captive colony, hoping to get some insight into the mechanisms of this aging difference.

Interestingly, in a long-term study of age-related decline in running speed and stamina in canyon lizards in Texas, biologists Ray Huey, Art Dunham, and Karen Overall found analogous results to this opossum work. In canyon lizards, females die at a faster rate than males. The evolutionary theory of aging predicts their physical decline should therefore begin earlier, which it does. These researchers are also comparing a low-altitude lizard population, subject to relatively high mortality rates, with a high-elevation, low mortality rate population. As the theory predicts, lizards lose their stamina at a younger age in the high mortality rate population. Running speed, puzzlingly, declines at similar ages in the two populations.

A great deal of evidence now supports the evolutionary theory of aging. But does this reveal anything about the prospects for retarding human aging? In one sense, the answer is a somewhat comforting "yes." In the industrialized West, at least, we have by and large conquered infectious diseases, and life is safer than ever. We are, therefore, living in an environment with reduced hazards. Reproductive rates are also down, and many people are choosing to delay reproduction. If these factors become global and if they are not outweighed by other, more insidious dangers of modern life, they should lead to an evolutionary slowing down of aging among humans. I suppose what comforts one person may not comfort another, but I am heartened to think that although it may take a few hundred generations or so, humans should one day be living longer.□

Seeds of Destruction

How sex triggers the aging of an orchid

With more than 30,000 species, the orchid family contains some of the world's most admired flowers, in shapes and colors diverse enough to satisfy nearly all tastes. But whether the flowers are delicately exquisite, lusciously sensuous, or simply bizarre, all this beauty has one very practical purpose: to attract pollinators that will fertilize the plant's egg cells. Once this is accomplished, the orchid turns its attention inward, to the all-important business of reproduction. As with all flowers, the cost to the blossom of this new life is aging and death, but for many orchids, dying takes much longer than the few days typical of other kinds of flowers. In orchids, the syndrome of developmental events leading to maturation and fertilization of the egg cells—a process triggered by pollination—may last as long as a year.

At its peak, this Philippine *Phalaenopsis violacea* flower is rosy magenta in color, just right to attract its insect pollinators. A day or so after pollination, the floral segments have begun to turn pale green and to fold ever so slightly inward. Three weeks later, most of the flower is green, and the ovary (at the base of the flower, looking almost like part of the stem) has begun to swell with the developing eggs inside.

Meanwhile, pollen tubes have begun to grow into the developing ovary in preparation for fertilization of the matured egg cell. Unlike many orchids, whose petals

Photographs by Allen Rokach

Special thanks to Keith B. Lloyd, curator of orchids, Sarah Davis Smith Memorial Orchid Collection of the New York Botanical Garden.

wilt following pollination, the now-green *P. violacea* petals are able to photosynthesize, providing nutrition for the developing ovary. The ovary will continue to swell for another two months, when the growing pollen tubes finally reach their mark and fertilize the mature ovule. Only now do the seeds begin to develop. Nearly a year after pollination, the new seeds mature and the ovary splits open, releasing up to 500,000 tiny seeds, harbored in a white cottony material. Then, the entire flower dries out and turns brown. Finally, we can pronounce it dead.

Working with orchid flowers, plant physiologists Sharman O'Neill (of the University of California, Davis), Abraham Halevy (of the Hebrew University of Jerusalem, Rehovot, Israel), and others have demonstrated how pollination triggers the developmental events that lead to ovule maturation, seed development, and ultimately, the death of the flower. Pollen, delivered to the orchid flower by a visiting insect, carries with it the plant hormone auxin. This hormone initiates two processes: the first elevates the sensitivity of petals and sepals (the perianth) to another plant hormone, ethylene gas, and the second leads to an increase in the amount of ethylene produced in the ovary and the perianth.

Without auxin, ethylene alone would quickly lead to the death of the flower, but together, the two hormones coordinate much of this orchid's complex reproduction, from the transformation of the perianth into a photosynthetic organ to cell division and differentiation of the ovary into a fruit. Eventually, however, the demands of the developing ovary and seed capsule become overwhelming, bringing the flower's long life to a close.—*R. F.*

A Shadowy Past

by Gail S. Cleere

February 2 is Groundhog Day, brought to us by nineteenth-century German immigrants. The day is all that is left of an ancient pagan celebration called Imbolog, which marked a "cross-quarter" day, one of the four days that fall midway between the four mileposts of the solar year, the spring and fall equinoxes and the winter and summer solstices.

On Imbolog, which means "sheep's milk," the early Celts marked the season of lambing, of driving cattle to the summer grazing lands, and of early spring planting. As in many pagan agricultural festivities, great fires were lit in honor of the sun. A belief arose that if this day were sunny, a long winter was forecast; if the day were gloomy, spring would be early. An early spring meant more than merely nice weather. An early planting meant an early harvest and an end to the hunger of a long winter. The conquering Romans learned this belief from the Scottish Celts and spread it to what is now Germany.

From early Christian times, February 2 was celebrated as Candlemas, with the presentation and lighting of candles. But the old pagan beliefs persisted. Good weather on Candlemas Day meant a second winter was coming. From medieval Scotland came the couplet, "If Candlemas be bright and clear, There'll be two winters in the year." From Cumbria, in northwest England, "If Candlemas Day be sunny and warm, ye may mend yer auld mittens, and look for a storm." And from Yorkshire, "A farmer should have, on Candlemas Day, half his corn and half his hay." But from Germany came the saying, "A farmer would rather see wife upon a bier, than that Candlemas Day should be sunny and clear."

German immigrants to Pennsylvania brought their folklore with them. They believed that North American marmots (woodchucks), which they called groundhogs, were able to predict the seasons.

Today, the groundhog's appearance is big business in Punxsutawney, Pennsylvania. If the weather is nice and the groundhog sees its shadow, another six weeks of winter are in store. The astronomical significance of February 2 has long since been forgotten. The necessity of watching the passage of the sun in the heavens to know when to plant and let the livestock out to pasture is gone, given way to a whole country watching for a groundhog.

Leap Years

Thirty days hath September,
April, June, and November;
All the rest have thirty-one,
Excepting February alone,
And that has twenty-eight days clear
And twenty-nine in each leap year.

This year, February has that extra day. For this, we can thank Julius Caesar (or at least the astronomers on his payroll), who changed the calendar to compensate for the quarter of a day beyond 365 days that the earth takes to travel around the sun. This quarter day accumulates into a whole extra day every four years. So, as part of the Julian Calendar Reform, instituted in 46 B.C., Caesar added a leap day to every fourth year.

Unfortunately, after Caesar's reform the calendar year was eleven minutes twelve seconds too long—an inaccuracy that probably mattered little to the Romans, but which had accumulated to ten days by the sixteenth century. In 1582, astronomers employed by Pope Gregory XIII recommended that ten days be chopped that year from the calendar, and that centennial years observe leap days only if the date is divisible by 400 (thus the year 2000 will be a leap year, the year 1900 was not). Those countries under papal authority adopted the Gregorian calendar. England and her colonies waited 170 years to accept it because they rejected papal ideas, regardless of merit.

But even the Gregorian calendar year is a bit too long. Over about 2,500 years, the Gregorian calendar itself will accumulate an error of one day.

The Planets in February

Mercury is behind the sun at midmonth, reaching superior conjunction, and will not be seen again until March.

Venus continues to put on a brilliant performance in the predawn southeastern sky, dazzling us at −4 magnitude. In the morning twilight of the 7th and 8th, Venus, Mars, Uranus, and Neptune gather within a few degrees of one another, very low along the horizon.

Mars, low in the southeast in the morning, moves quickly eastward out of Sagittarius and into Capricornus this month. Just before sunrise on the 1st, Mars is visited by the thin crescent moon. On the 19th, the red planet is in conjunction with Venus, and the two planets will appear extremely close in the predawn sky, with Venus greatly outshining Mars.

Jupiter maintains a lonely evening vigil this month, gliding across the cold February sky with only the stars of Leo as a backdrop. On the 18th, a full moon passes close by but doesn't stay long. On the 28th, Jupiter reaches opposition (opposite the sun in our sky), rising when the sun sets and setting when the sun rises.

Saturn emerges from behind the sun as a morning object in Capricornus, becoming visible during the second half of February. Venus passes very close to Saturn on the 28th.

Uranus and **Neptune** stay within a few degrees of each other all year and can be spotted in dark skies with binoculars. This month, they are morning objects in Sagittarius, squeezed in between Venus and Mars at the beginning of the month. To easily locate these dim planets, you should consult the special star maps published in popular astronomy magazines.

The **Moon** is new on the 3d at 2:00 P.M., EST; first-quarter moon is on the 11th at 11:15 A.M., EST; full moon, on the 18th at 3:04 A.M., EST; and last-quarter moon, on the 25th at 2:56 A.M., EST.

Gail S. Cleere writes on popular astronomy and is a founding member of the International Dark Sky Association, an organization dedicated to preserving the skies for astronomy.

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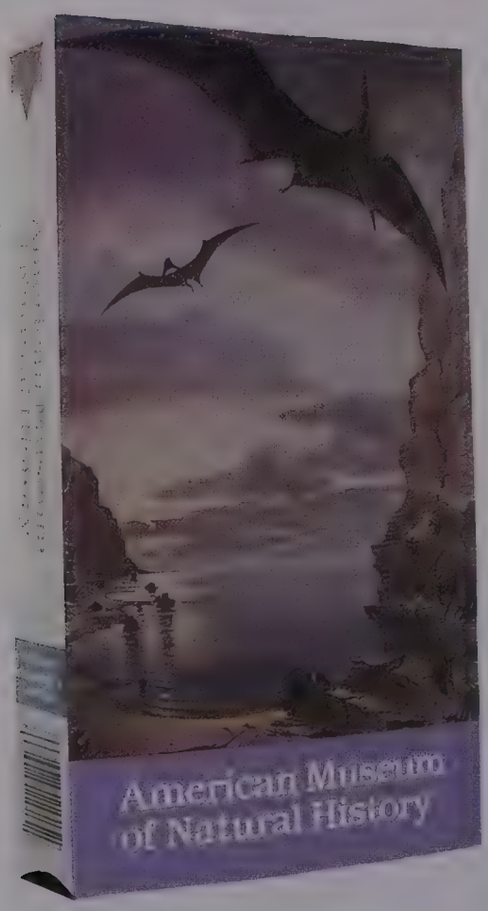

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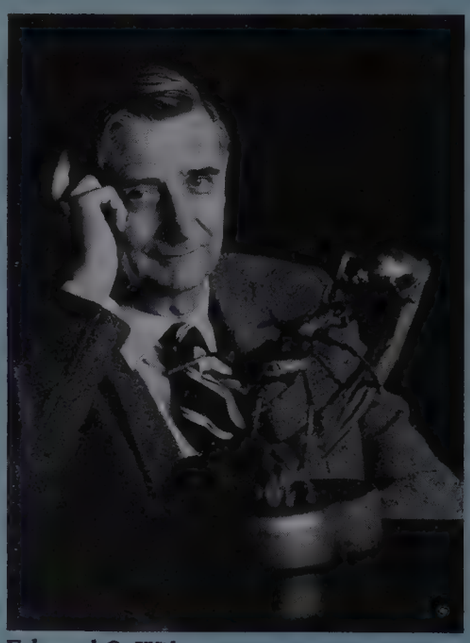
At the American Museum

Man and Nature Lecture

Edward O. Wilson, Frank B. Baird Jr. Professor of Science and curator of entomology at Harvard University's Museum of Comparative Zoology, is best known for his award-winning scientific work on ants and as the premier theorist of sociobiology, the field that examines the evolution of social behavior.

Wilson has been chosen to present the 1992 Mack Lipkin Man and Nature Lectures at the American Museum of Natural History. This public lecture series



Edward O. Wilson

gives prominent scientists an opportunity to discuss their work and its importance for humanity. On Monday, March 2, Wilson will discuss the implications of the accelerating extinction rate, which threatens to destroy myriad plant and animal species at a time when biodiversity is at one of its highest points in our planet's history. On Tuesday, March 3, Wilson will talk about the colonial adaptations that have enabled ants to survive for more than 50 million years.

Both lectures will begin at 7:00 P.M. in the Main Auditorium. Advance admission for the two-evening series is $30 ($20 for members); for one evening, $20 ($15 for members). Tickets may be ordered from the Membership Office, American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024-5192. Call (212) 769-5606 for further information.

Black History Month

The Museum will celebrate Black History Month with programs ranging from African folklore to women writers in the black arts movement to the origins of gospel music. Free with admission to the Museum, the events will take place from 1:00 to 4:00 P.M. every Saturday and Sunday in the Leonhardt People Center.

A five-member a cappella ensemble, No Name Gospel Singers, will present African American sacred music on Sunday, February 2, at 2:00 and 4:00 P.M. Mickey D and Friends will trace African American jazz dancing on Sunday, February 9, at 2:00 and 4:00 P.M. Katherine Prestwidge, professor of biology and medical lab technology at Bronx Community College, will discuss the contribution of African Americans to the science, technology, engineering, and health professions on Tuesday, February 11, at 7:00 P.M. Urban anthropologist Sherrill D. Wilson will talk on the history of African Americans in New York, as slaves and as free people, on Wednesday, February 19, at 7:00 P.M. These programs will take place in the Kaufmann Theater.

Contemporary dance genres will be explored by the Nanette Bearden Contemporary Dance Theater on Wednesday, February 5, at 7:30 P.M. in the Main Auditorium. A tribute to American jazz composer Mary Lou Williams and an African village ritual dance to the recorded music of master drummer Olatunji are among the presentations.

Seating is on a first-come, first-served basis. No tickets are necessary, but seating is limited. These programs, presented by the Museum's Department of Education, are made possible in part by a gift from the family of Frederick H. Leonhardt and by a grant from the Chase Manhattan Bank. For a full schedule of events, call (212) 769-5315.

Ring of Fire

The new IMAX film opening on January 11 in the Naturemax Theater is about

the boundary in the earth's crust where more than three-quarters of the world's active volcanoes are located. *Ring of Fire* follows a 30,000-mile circle around the Pacific rim—from Mount St. Helens in the United States to Chile's Navidad, Japan's Sakura-jima, and Indonesia's Mount Merapi—and looks at the people and cultures within this volcanic ring. A team of geologists, anthropologists, computer animators, and filmmakers worked for more than seven years on this project.

Showtimes are every hour from 10:30 A.M. to 4:30 P.M. daily. On Fridays and Saturdays at 6:00 P.M. and 7:30 P.M., *Ring of Fire* will be shown with another IMAX film, *We Are Born of Stars*. For information, call (212) 769-5650.

The Magellan Mission to Venus

The most recent Magellan Mission results will be the subject of a lecture by Steven Squyres, associate professor of astronomy at Cornell University. This talk is part of the Frontiers in Astronomy and Astrophysics Lecture Series and will take place in the Planetarium's Sky Theater on Monday, February 24, at 7:30 P.M. Tickets are $6 ($5 for members). For information about other Planetarium events, call (212) 769-5920.

Reflections in Natural History

Stephen Jay Gould, Alexander Agassiz Professor of Zoology and professor of geology at Harvard University, will talk about a variety of topics in the field of evolutionary biology on Tuesday, February 11. Gould is a research associate in the Museum's Department of Invertebrates and a regular columnist for *Natural History* magazine. The lecture will be held in the Main Auditorium at 7:00 P.M. Tickets are $30 ($20 for members). For information, call (212) 769-5606.

These events take place at the American Museum of Natural History, located on Central Park West at 79th Street in New York City. The Kaufmann Theater and the Leonhardt People Center are located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

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Mill Creek Cove, Texas

by Robert H. Mohlenbrock

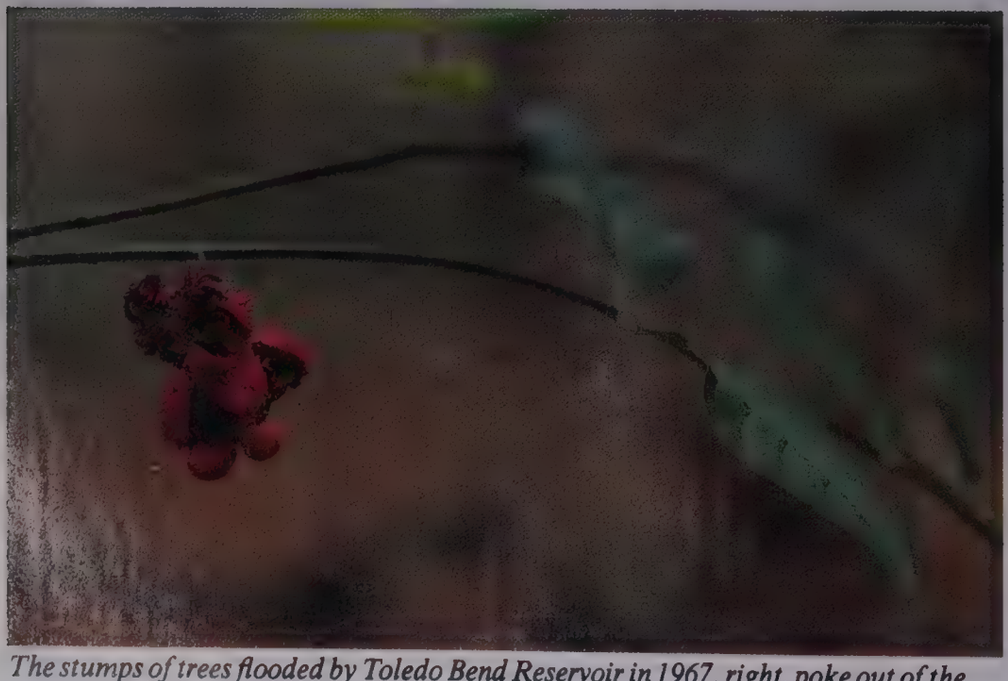
Although southeastern Texas is commonly referred to as the East Texas Pineywoods, majestic forests composed chiefly of American beech and southern magnolia sometimes prevail in the rolling, southern part of the region. These broad-leaved trees thrive where the soil is moist but well drained, such as near the foot of a hill. During the past century, many such forests, which resemble those of the Appalachian foothills hundreds of miles to the east, have been destroyed or disturbed by human activities, including the creation of huge reservoirs. One ninety-four-acre tract that has been spared is Mill Creek Cove, located in the Sabine National Forest between two arms of the Toledo Bend Reservoir.

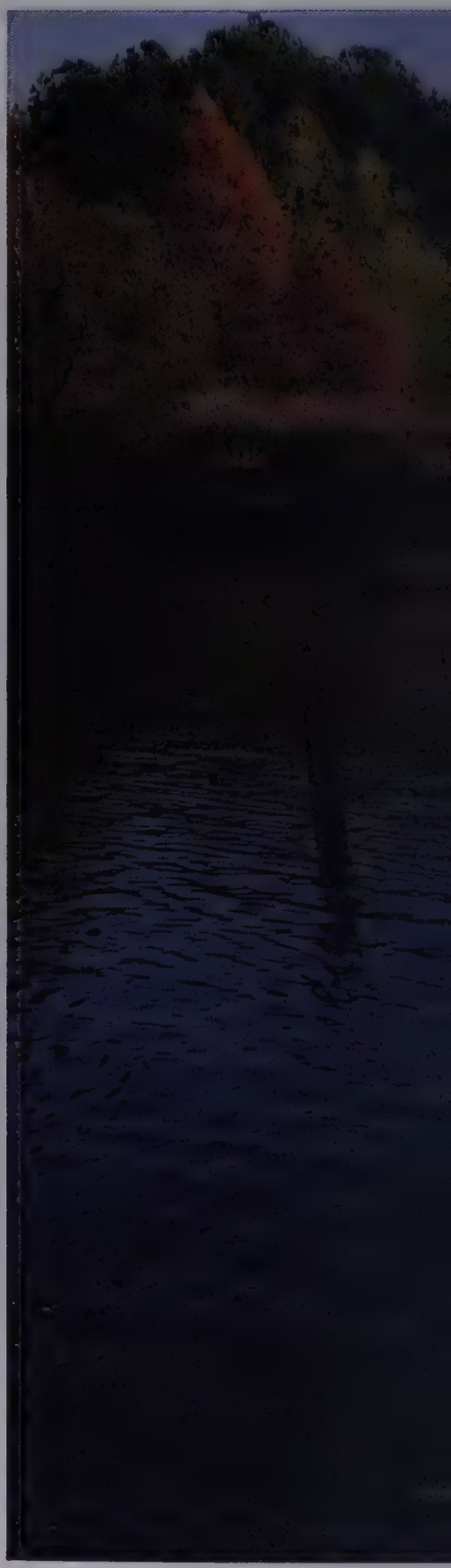
Woody plants form three distinct layers, or canopies, in Mill Creek Cove. The upper canopy forms the forest's cathedral-like ceiling and averages about 100 feet high; it is dominated by American beech and southern magnolia, with an occasional tall sweet gum, white oak, water oak, and green ash. Some of the beeches and magnolias are more than 120 feet tall, with diameters of nearly four feet at shoulder height. This upper canopy is completely closed except for an occasional small opening where a large tree has died.

Musclewood, hop hornbeam, black gum, flowering dogwood, and the evergreen American holly grow twenty-five to fifty feet tall. All these midcanopy species are able to thrive in the heavy shade cast by the taller trees. Beneath the midcanopy is the shrub layer, where shrubs and trees seldom grow more than fifteen feet high. The species found there include yaupon holly, beautyberry, highbush blueberry, styrax, witch hazel, and Carolina buckthorn. These last two are capable of growing twice as tall where light is more abundant.

Because of the deep shade, there are no brushy thickets or entanglements of vines on the forest floor, giving Mill Creek Cove a nearly parklike appearance. What vines exist—such as the southern muscadine grape, yellow jasmine, cross vine, and Virginia creeper—seek sunlight by climbing the nearest tree and do not sprawl across the leaf litter. Except for some scattered plants of jack-in-the-pulpit and hound's-tongue, wildflowers are scarce. Only partridgeberry, with its deep green, penny-sized leaves, lies in patches on the ground.

The distinct breaks between the different canopies in Mill Creek Cove reflect the dominance of a limited number of species, the result of competition over an

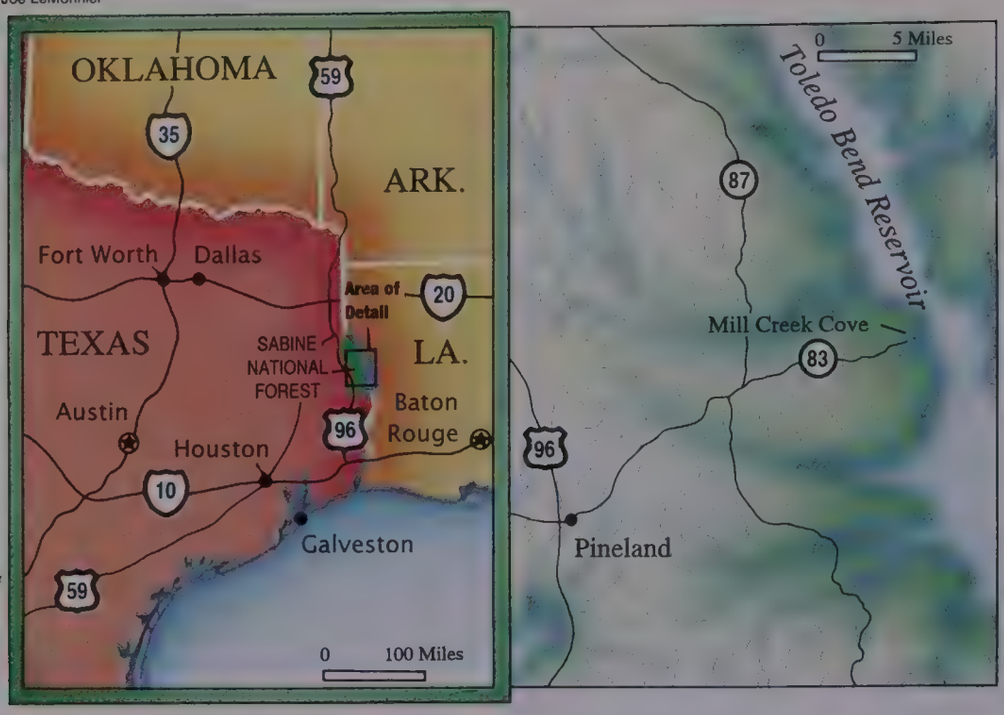




The stumps of trees flooded by Toledo Bend Reservoir in 1967, right, poke out of the water near Mill Creek Cove. Above: Strawberry bush.

Photographs by Jay B. Simon

Joe LeMonnier



Mill Creek Cove

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An egret flies by Mill Creek Cove.

extended period of time. This suggests that this is a virgin forest. Botanist E. S. Nixon and his colleagues, who have studied the woody plants in Mill Creek Cove, have also noted an abundance of beech and southern magnolias of every size and age, another clue that this forest has not been cut. Because the growth of the younger trees will renew the dominant species, Mill Creek Cove is a climax beech–southern magnolia forest—the only one, according to botanist Steve Orzell, on the West Gulf Coastal Plain, a region that extends around the Gulf of Mexico from Mobile, Alabama, to Galveston, Texas.

Ecologists use the term *climax* to refer to the final stage in a natural succession of plant communities in a specific environment. In an area such as Mill Creek Cove, for example, the first plants to colonize bare ground are primarily annuals, plants that grow from seeds, reproduce, and then die back each year. As the annuals die, their organic remains contribute to the soil and build up its capacity to retain water. After a year or two, this provides a suitable habitat for perennial herbs to become established. The perennials usually grow taller than the annuals, shading them out.

As the soil becomes richer and more capable of holding water, more robust perennials appear. Shrubs and eventually trees come to dominate. The climax is reached when the forest community consists of plants that continually replace themselves, rather than paving the way for a succeeding stage.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U. S. national forests.

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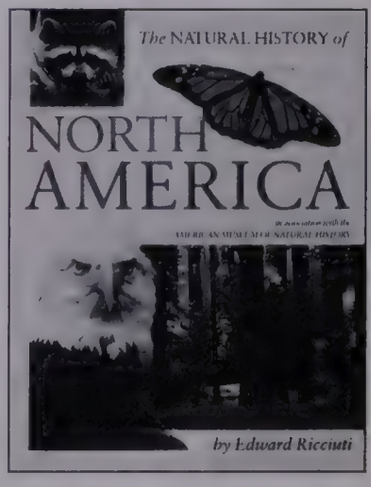

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Cracking the Brain Case

by Ira B. Black

In the past decade, new approaches and emancipating discoveries have revolutionized our understanding of the brain and mind. Recombinant DNA technology, new brain-imaging techniques, brain cell culture, and the computer revolution are yielding information at an explosive rate. We are beginning to understand the relationship that exists between brain genes and cognition. The physical bases of learning and memory are emerging. New and ingenious experiments are revealing the overall organization of cognitive life and our emotions.

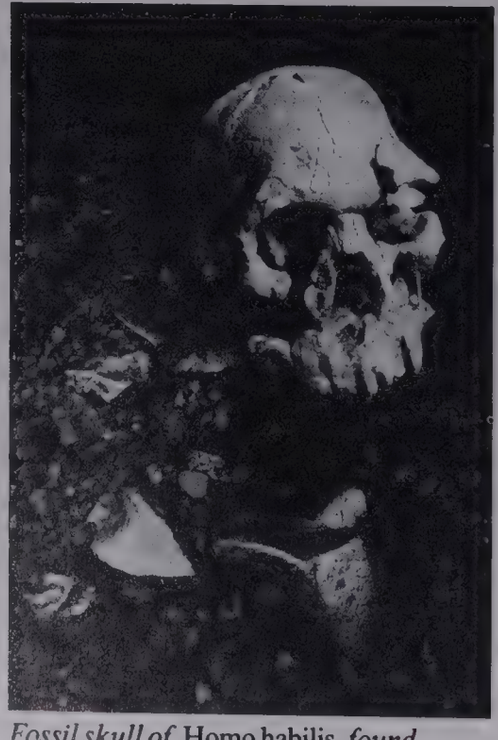
How did the human brain evolve? Indeed, what cognitive capacities and personality traits, if any, are uniquely human? What is the broader evolutionary context for the biology of brain and mind function? These are just some of the questions that paleoanthropologists in general, and Dean Falk in particular, have taken as their challenge.

In *Braindance,* Falk employs a conversational, frequently polemical vehicle to present her views of hominid brain evolution, treating the reader to a generous subtext concerning the sociopolitics of paleoanthropology. While her use of hyperbole, loose analogy, and anecdote are often distracting, she does provide a much-needed orientation to the contentious field of hominid brain evolution. Even her subjective, sometimes rancorous accounts of controversies with intolerant, competitive adversaries provide a glimpse of the rough-and-tumble of science.

BRAINDANCE, by Dean Falk. *Henry Holt and Company, Inc., $24.95; 272 pp., illus.*

In Falk's view, human brain evolution is predicated on the emergence of frontal lobe function, the development of associational cortex, and the lateralization of brain function—that is, the growing asymmetry of the two cerebral hemispheres. The frontal lobes, lying above the brow at the front of the brain, are essential for creativity, initiative, personality, and subjective awareness. The associational cortex, on the other hand, builds up ever more complex associations of information relayed from the sensory areas. This is where, for example, the appearance, sound, and emotion attached to an experience are associated in memory. Not surprisingly, Falk focuses on frontal lobe function and associational cortex evolution to explain hominid evolution.

Falk traces frontal and associational phylogeny in the lineage from *Australopithecus gracilis* to *Homo habilis*, *H. erectus*, and the present keeper of the flame, *H. sapiens*. While her formulation provides a useful neuroanatomical and anthropological road map, it misses a central conceptual mark. Her account implies that hominid brain evolution is about the selection of an ever better, all-purpose thinking machine. In contrast, modern cognitive and neuroscientific discoveries suggest that the primate (and human) brain is composed of diverse, highly specialized cognitive subsystems, not a single universal thinking engine (*see* "Mozart and Modularity," page 8). But we're jumping ahead. Let's describe Falk's views in greater detail.



Fossil skull of Homo habilis, *found at East Turkana, Kenya, in 1972.*
John Reader, Science Photo Library

Assailing the paleoanthropological "old guard" and "old boys club," Falk argues that Raymond Dart's Taung "child" actually had an apelike brain, not the human-like brain claimed by the discoverer (*see* "Taungs and Its Significance," *Natural History*, April 1980). Similarly, Donald Johanson's 3-million-year-old Lucy (*A. afarensis*) is excluded as the link to the genus *Homo*. In Falk's view, the real point of departure is Mary Leakey's startling discovery in 1978: fossilized footprints at Laetoli, dating from 3.5 million years ago (*see* "The Pitted Pattern of Laetoli Feet," *Natural History*, March 1990). And here Falk begins an engrossing epic.

Falk is at her best inferring that the hominid brain began its explosive growth 1.5 million years after the walk at Laetoli. In other words, the bipedal Laetoli hominid had an apelike brain and was probably the common ancestor of modern hominids. Moreover, the dissociation of bipedalism and brain growth prompts Falk to dismiss a host of theories that have

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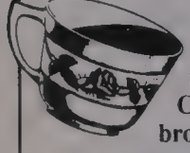

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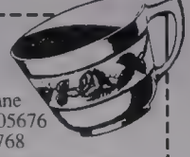

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related hominid brain evolution to erect posture. In place of the scenarios that she now finds implausible, Falk enunciates "the radiator theory of brain evolution."

Setting the stage for her theory, she notes that normal brain function requires a rather narrow temperature window. She then takes us for a walk in the sun-baked savanna, with the solar orb beating down on the heads of our upright ancestors. The combination of the hot sun and the new stresses on cerebral blood flow induced by gravity acting on a now-erect animal places limits on brain growth.

In Falk's view, the evolution of "a cranial radiator system of veins" allowed cooling of the brain and removed the major limitation on brain growth (*see* "The Petrified Brain," *Natural History*, September 1984). Falk also notes common features in the brain venous sinuses of gracile australopithecines and hominids, which differ from those of *A. afarensis* and *A. robustus*, and she constructs the lineage accordingly. *A. gracilis* led to the hominid line in which brain size increased so dramatically.

Emancipated by the brain vein drain, the cerebral organ was free to respond to selective pressures. Falk asserts:

> Since the time of Darwin, there have been many speculations about possible prime movers of human brain evolution. Some of these have been rather fanciful. Among the nominees are warfare, work, language, tool production, throwing, and hunting. Despite all the speculation about prime movers, there seems to have been resistance to the simple possibility that brain size increased as a result of selection for general intelligence.

Here Falk gets into neuroscientific difficulty by treating the brain as a single system.

In fact, the particular mechanisms mediating the expansion of the frontal cortex and associational areas and the elaboration of lateralization, so important to Falk, are never adequately explicated. Yet the particulars of the evolution of specific subsystems lie at the crux of the scientific problem. To appreciate potential difficulties with Falk's stance, let's place paleoanthropology in a neuroscientific context.

A sampling of some recent advances in neuroscience may put this enormous task in perspective. The human brain contains approximately 100 billion neurons, each with about 10,000 specialized junctions, or synapses, that communicate with other neurons. Activation of billions of synapses at a time results in body movement, a perception, or thought.

Chemical signals, or neurotransmitters,

transfer information from one neuron to another in thousandths of a second. Neurons convert the transmitter signals into electrical impulses that are carried along neural cables to the next synaptic junction. There, another transmitter jumps the gap, communicating with the next neuron in line. These basic, building-block synaptic mechanisms are present even in such simple life forms as coelenterates.

In humans, the synaptic networks are organized into diverse systems serving different, highly specific functions. We now know that individual neurons use multiple transmitter signals to convey information to other neurons. In effect, each of the 100-billion neurons can act as a picocomputer, integrating vast amounts of information. Even at the level of the single neuron, complexity and the capacity for sophisticated processing are apparent.

Recent discoveries indicate that the genes that produce transmitters are controlled by the environment. For example, stressful environmental events elicit the well-known fight-or-flight response by activating genes that trigger adrenaline and noradrenaline secretion. In essence, the neuron translates environmental events into behavior through gene action. Thus, the environment shapes neural function during an individual's lifetime, while selecting for neural functions during evolutionary time. Falk misses the opportunity to integrate these new insights.

Startling discoveries now indicate that brain neurons use chemical growth factors, as well as transmitters, to communicate. These factors, also secreted in response to environmental stimuli and nerve impulses, cause growth of new and stronger nerve pathways. In other words, environmental activation of a neural circuit may increase its size and effectiveness by causing growth factor secretion. Growth factors may also play a role in evolution, regulating expansion of old neural systems and eliciting growth of new systems and functions. Unfortunately, Falk does not explore these emerging relationships between the environment, the individual, brain genes, growth factors, and evolution.

How has selection organized these molecular and cellular mechanisms into functioning cognitive systems? How is the functioning cognitive system organized? Converging evidence from neurology, psychology, and neuroscience suggests that cognitive function is organized into discrete modules, which were well summarized by Michael Gazzaniga, professor of psychiatry at Dartmouth, in his article "Organization of the Human Brain" (*Science*, vol. 245, 1989). Apparently unified mental life is actually composed of multiple, distinct components. Different brain areas perform different mental functions, and disconnection of areas prevents normally integrated mind function. Mentality literally disintegrates.

For example, the curious and tragic syndrome of alexia without agraphia—when a person cannot read but is able to write—owes its existence to modularity. In this disorder, visual areas become separated (as a result of strokes) from the receptive language area (Wernicke's area), preventing reading. However, since language is *expressed* by the separate motor language area (Broca's area), writing is not impaired.

Of course, modularity is apparent in normal sensory processing as well. For example, when we look at an object, we analyze color, motion, and depth perception along separate synaptic pathways, but the result is a unified perception.

Modularity of cognitive function represents one organizing principle of brain action. In turn, modularity is one manifestation of lateralization, the asymmetry of right and left brain function that Falk perceptively cites as a key to hominid brain evolution. In chapter 5 of *Braindance*, Falk summarizes the work of Roger Sperry, professor of biology at the California Institute of Technology, who studied brain asymmetry in animal models in the 1960s. Gazzaniga, a graduate

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student, applied the research to humans, with astounding results.

In the 1960s and 1970s, Gazzaniga performed landmark studies of so-called split-brain patients. These individuals had intractable epilepsy, which caused electrical seizures to spread from one cerebral hemisphere to the other. They were helped by surgical separation of the two halves of the brain, which transected the massive fiber bundle connecting the hemispheres. The procedure prevented seizure spread, but it also prevented the interhemispheric transfer of information. The stage was set for some fascinating observations.

In one series of experiments, Gazzaniga flashed a frightening scene of a burning building to the mute right hemisphere of a patient's brain (only the left had language function). The patient became anxious and agitated. When asked what was wrong, the verbal left brain, not having observed the scene, made up stories. In experiment after experiment, the verbal left brain fabricated explanations, theories, and hypotheses to explain experiences originating in the inaccessible, mute right brain.

These landmark studies led to a number of insights, some directly relevant to human brain evolution. The obvious asymmetry of the brain's left and right hemispheres argues for the differential localization of function as a general principle of brain (and mind) organization.

In addition, a specific module that Gazzaniga terms the interpreter is found only in the dominant left verbal hemisphere. The interpreter constantly attempts to bring unity to a modular consciousness and to the discontinuities of internal and external reality. Apparently, the mind prefers an incorrect explanation to no explanation at all.

In the split-brain patients, the interpreter was always found in the dominant left hemisphere, along with language. In some deep, yet unrecognized manner, therefore, interpreter function and language may be closely related. And few would argue with the contention that language function is uniquely human.

In spite of some controversial claims in the 1960s, most scientists agree that chimpanzees never learn the human equivalent of language. After three decades of work, David Premack, professor of psychology at the University of Pennsylvania, one of the leaders in the field, points out that although chimps can learn a type of artificial representation system, it is distinct from human language. Children use words as representations, employing both abstract and imaginal codes that result in syntactic constructions inaccessible to

chimps. By comparison, chimp "language" is invariant and impoverished. Falk tends to gloss over these critical differences, thereby missing central points concerning the nature of human intelligence and the type of evolutionary processes that must have occurred.

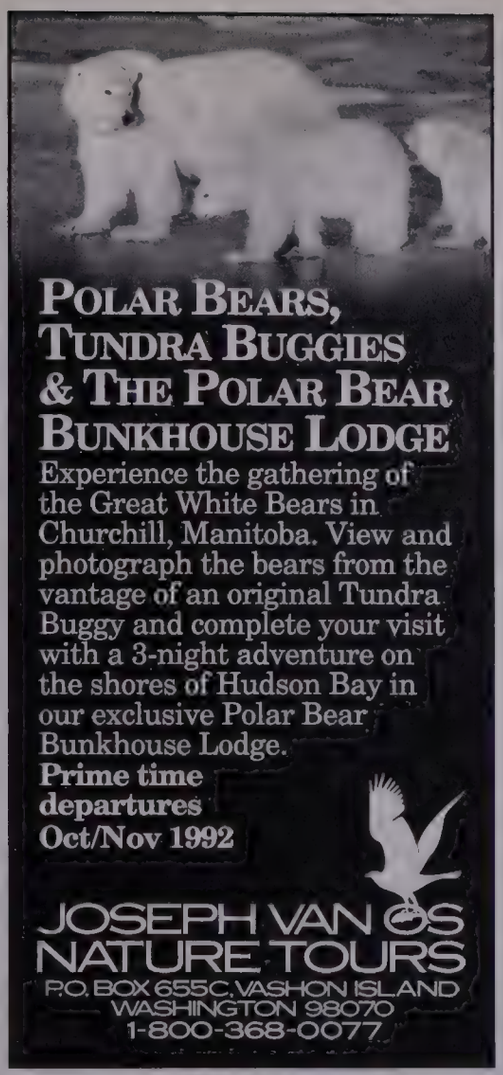
In her enthusiasm for the cleverness of chimps, Falk confounds general intelligence and language. To disentangle the two and get back on the evolutionary track, we must understand the message of language scientists. Simply stated, language is a highly specialized cognitive capacity, not a characteristic of a generalized cognitive machine.

In his classic work, *Syntactic Structures,* MIT linguist Noam Chomsky pointed out that in spite of the apparently endless variations among some 4,000 extant languages, a common grammar seems to be built into the human brain. (Linguists use the term grammar to denote a mental structure for mapping meaning onto sound for the production of speech, and conversely for decoding.) An Oxford don, a South Foré tribesman in New Guinea, and a !Kung bushman obey the same underlying grammatical rules.

The implications of Chomsky's formulation for hominid brain evolution are profound. The human brain has a subsystem specialized for language. Extensive clinical evidence supports the contention that language and general cognition are dissociable. Animals and infants exhibit normal cognition without language. Aphasic stroke patients display normal intelligence. Conversely, demented patients are often able to speak relatively normally but are virtually devoid of the most rudimentary problem-solving ability. An explanation of human brain evolution based on the phylogeny of a general intelligence, as invoked by Falk, just won't do. Any account must describe mechanisms governing the emergence of a specialized language system in the human brain.

Falk does, however, acquaint the reader with some important introductory material. The general scheme of cortical organization is outlined, the potential evolutionary roles of prefrontal and associational cortices are summarized, and the concept of lateralization is introduced. This information may equip the reader to deal with some of the thornier issues of human evolution.

Ira B. Black is professor and chairman of the Department of Neuroscience and Cell Biology at the Robert Wood Johnson Medical School/UMDNJ and author of Information in the Brain: A Molecular Perspective.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The Raw and the Cooked

In Pacific Asia, enthusiasm for raw fish dishes reaches its zenith

by Raymond Sokolov

Claude Lévi-Strauss long ago noted that raw and cooked food were the opposite poles of a fundamental axis of human culture. He was primarily concerned with myths as windows on the structure of the mind. In actual waking life, most of us spend very little, if any, time pondering the significance of these culinary antipodes. Our reflex when we mention food is to think of it as cooked. Obviously, we are aware that food in the state of nature is always raw (unless it is struck by lightning or roasted in a forest fire), but perhaps as a consequence of our high state of civilization, our reflex is to put "food" in the mental cubbyhole marked "cooked."

In the lingo of computers, cooked is the "default" for the food "parameter." We would have to reconfigure the program in our heads to have the thought of food automatically imply something edible *and* uncooked. What this means when we sit down at the table is that we see nothing strange if we are served a pork chop that has been laboriously breaded and sautéed but feel ourselves on the brink of a small adventure, a gastronomic special occasion requiring, at least the first time we do it, special moxie when we set out to tie into raw oysters, clams, or sashimi. As Jonathan Swift said: "He was a bold man who first eat an oyster."

We also shiver when we make our debut with steak tartare (the name itself underlines the nomadic, bloodthirsty aura of the dish). But culinary custom has made steak tartare and the other standard raw dishes a macho minicuisine, a socially acceptable enclave of uncooked delicacies. When we eat raw food that lacks the sanction of custom, we enter a truly wild and uncharted forest.

Imagine how repelled you would be by a plateful of raw chicken parts. And the shock of that pales by comparison with my horror at the raw deer liver I once was shamed into devouring by the chef-hunter who offered it to me as a special treat: blue, quivering, and cold. Worse still was the dinner party I went to long ago where the absent-minded hostess forgot to turn on the oven and didn't notice until the moment of truth that she was about to serve pork tartare instead of a roast.

This aversion to raw flesh is curious because it is the reverse of the prejudice we ought to expect, given that we normally recoil instinctively from what is furthest from the state of nature. But with food, particularly meat, we reject the natural (raw) in favor of the artificial (cooked). To compound the paradox, we take the opposite position with regard to fruits and vegetables, happily eating them raw whenever possible and even abandoning certain fruits, such as quinces and gooseberries, that can't be eaten out of hand.

This set of prejudices, which strikes me as an undeclared predisposition toward vegetarianism or at least a squeamishness about animal protein, is not a human universal. Although, so far as I know, all cultures cook meat at one time or another (with the exception of completely vegetarian religious sects), some cultures are much more tolerant of, and even avid for, raw food. I am thinking of Japan, Korea, and the Philippines. No doubt, a sweep of the anthropological literature would turn up other cultures that put a premium on raw food, but among the industrialized nations, these three populous Asian societies are obviously remarkable for their eagerness to eat raw food, especially raw seafood.

Why should this be? Before all else, these are nations surrounded by the Pacific. Japan and the Philippines are composed of islands; Korea is a peninsula. The technically complex, aesthetically elaborate vocabulary of raw fish dishes developed by the Japanese for sashimi and sushi are perhaps the most widely disseminated artifacts of Japanese high culture. Even the most insensitive sushi-bar neophyte must be at least dimly aware that

Japan, the Philippines, and Korea have each developed an elaborate repertoire of raw fish dishes. Above: Sushi.
David Doubilet

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she or he is experiencing an artistic sublimation of fish and shellfish in which the variations in texture, grain, shape, and color of the raw materials, so to speak, rival in importance, if they do not surpass, the significance of the taste. It seems clear that the taste of raw fish for the Japanese must be an aestheticized facet of the sushi experience in the same way and to the same degree as color, grain, and so forth.

Koreans have their own raw food recipes. There is a sesame-flavored steak tartare called *yukhae,* and less commonly, you will encounter raw squid cut into rings and served in a hot sauce. There are other raw Korean foods, but in Korean restaurants most of the raw food served is Japanese and presented as such.

As you enter many Korean restaurants, the first thing you see is a full-blown sushi bar. Many Korean menus also have a page devoted to more or less authentic sushi. What might appear to be cultural subservience is really something more intricate, since Korea historically absorbed the cultures of its neighbors—and influenced them—without losing its own soul.

For the outsider, however, all these aesthetic and cultural considerations take a back seat to the overall effect—of purity and freshness—that raw food has on the mind and palate of the eater. It is this primal feasting on food in the state of nature that gives raw food its special impact.

In between the absolutely raw and the absolutely cooked—between sashimi and a well-done burger—is ceviche (also spelled cebiche and seviche), the popular method of "cooking" seafood in citrus juice familiar from the cuisines of Mexico and Peru. There are several competing theories that purport to explain the origin of this technique, in which the acid of the juice, classically the juice of the true, or Key, lime, breaks down the flesh of the fish or shellfish, turns it opaque, and makes it deliciously tender. This process takes a couple of hours and leaves the seafood almost as cooked as if it had been subject to the heat of a stove or oven, but the flavor is different and the texture more delicate.

In Lima today, lifelong aficionados of ceviche are intrigued by a new twist in the cookery of the almost-raw, a method called *tiradito,* in which the seafood is immersed in juice for a shorter time and retains much more of its fresh feeling and chewy texture. *Tiradito* is said to reflect the presence of significant recent Japanese immigration to Peru (the leading example being Peru's President Fujimori). Peruvians will tell you that *tiradito* is as close to sashimi as you can get without having sashimi itself. This may be, but *tiradito* is a relatively narrow example of a style of cooking that has been in full flower on the other side of the Pacific for centuries, and not in Japan.

The multifarious peoples of the Philippine archipelago have an encyclopedic repertoire of almost-raw food, which they call *kinilaw.* The basic idea is brilliantly simple. You can try it yourself. Take a shrimp. Shell it. Remove the sand vein if you care, and then immerse the shrimp in vinegar for a short while, less than ten minutes. Take a bite. Then, if you really want to be scientific about *kinilaw,* compare the vinegared shrimp with a completely raw one. You should notice a basic difference in appearance: the *kinilaw* shrimp will be cloudy or opaque, while the raw shrimp is translucent. The *kinilaw* shrimp will taste almost raw but will have the very gentlest aura of being cooked. You could say that the *kinilaw* shrimp stands on the border between the raw and the cooked, combining the virtues of nature and culture in one delicious and delicate morsel.

This is the paradox expounded in an appropriately slim and elegant volume just published in Manila by those learned and indefatigable gastroethnographers Edilberto N. Alegre and Doreen G. Fernandez: *Kinilaw: A Philippine Cuisine of Freshness.* In researching this ancient method of fireless cooking, Alegre and Fernandez traveled widely from island to island, uncovering an immensely ramified system of recipes and souring agents, as well as a vocabulary of astonishingly refined terms for degrees of rawness. They were ultimately compelled to organize their information in a sprawling grid to allow the reader to get a grip on the geographical and linguistic differences, as well as the culinary variations, of *kinilaw* cookery across the Philippine archipelago.

The vinegars themselves differ subtly as to source, coming from coconut, nipa palm, and sugar cane. Then there is an almost infinite array of flavorings—salt, ginger, onions, coconut milk—that go into the vinegars or the citrus juice or other sour fruit juices. This is also an aesthetic value system that distinguishes between subtle degrees of resistance to the tooth and focuses with specific terms on a food's liquid content or viscosity: its "liquid aspect" (*lusaw, malabnaw, malapot*) and its "solid aspect" (*basa, panat, tuyo*). Alegre writes about such notions as *look,* "watery and crumbly, like the inmost core of watermelon," and *looy,* "the degree past crunchiness," of cooked swamp cabbage (*kangkong*) leaves and stems. "*Hinga,*" he observes, "is the state of *labanos* [white radish] after a day or two: when fresh it is translucent, all-white, crunchy and moist, that is, *malutong;* later the whiteness becomes opaque, its crunch moves to a soft, crumbly stage, and its wetness is no longer uniform but spotty. This is *hinga.*"

Such concepts—and there are many more—are applied to the appreciation and judgment of the *kinilaw* menu, which has been extended to soured preparations of vegetables and even red meat. But despite its extremely refined aesthetic, this is not an aristocratic form of eating. Instead, think of *kinilaw* as the ultimate in fast food, beach food, something anyone can do in a trice and then think about, bite by bite. Raw but not crude.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

Cebiche di Almejas
Clam Ceviche

(Adapted from *The Art of South American Cooking,* by Felipe Rojas-Lombardi, HarperCollins, 1991)

5 cups shucked clams (about 100 cherrystones), drained
¾ cup lemon juice (4 or 5 lemons)
2 jalapeño peppers, seeded and minced
1 teaspoon coarse salt
3 large new potatoes, washed, cooked, and cut into ½-inch cubes
2 large tomatoes cut into ½-inch cubes
1 small Bermuda onion, peeled and thinly sliced
¼ cup olive oil
3 tablespoons chopped fresh cilantro leaves or dill
8–16 Boston lettuce leaves

1. In a stainless steel or glass bowl, combine the clams, lemon juice, peppers, and salt. Mix, cover, and place in the refrigerator to marinate for about 2 hours.
2. Remove the bowl from the refrigerator and add the potatoes, tomatoes, and onion. Toss and let stand for 5 minutes at room temperature. Add the olive oil, toss well, correct seasoning with salt to taste, and sprinkle with the cilantro or dill. Serve on Boston lettuce leaves.

Yield: 8 to 10 servings

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The Natural Moment

Afternoon of a Yawn

Waking up is never easy. After emerging from his den in Alaska's Denali National Park late one autumn afternoon, this male red fox yawned widely. Pausing among the bearberry plants near the crest of a hill, he briefly surveyed the tundra below, then trotted off, perhaps to hunt for mice and rabbits. With few exceptions, yawning is universal among vertebrate animals, according to Ronald Baenninger, a psychologist at Temple University in Philadelphia who studies the phenomenon. Yawning dogs and cats are familiar; but birds, reptiles, and even fish also yawn—probably for similar reasons. Baenninger has found that carnivores tend to yawn more frequently than herbivores, a difference he attributes to a meat eater's need to be alert while hunting. He observed that even lions in the Philadelphia Zoo, which don't have to hunt for their meat, yawn most just before feeding time—the high point of their day. In people, yawning seems to serve a similar purpose. Baenninger's research suggests that at times when falling asleep carries a high price (while driving late at night, for instance), yawning increases alertness. Once the driver is in bed, trying to sleep, yawning usually stops. The notion that yawning is merely a deep breath, triggered by the bodily need to increase oxygen intake, is no longer accepted. What seems to be more important about yawning is its arousing effect on the brain, but the details of how that occurs are still poorly understood. And the contagiousness of yawning has also not yet been explained. (Did this picture make you feel like yawning?)—*R. A.*

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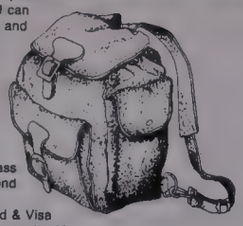

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AUTHORS

Steven Austad (page 24) may, as he says in his article, have had an interest in the question of aging since he was a child, but he has hardly been a slave to the topic. His career began with a degree in English literature and has included stints as taxi driver and lion tamer. Currently, he is an associate professor of biology at Harvard University. For the past several years he has concentrated his fieldwork on various aspects of the reproductive biology and aging of the Virginia opossum. He recently began, together with graduate student Kathleen Fischer, a study of the ecology and conservation of montane cuscuses (arboreal, fruit- and leaf-eating marsupials) in a remote corner of Papua New Guinea. When he is at home, pets continue to occupy nearly as much of his time as they did years ago, but they are no longer all named Spot.

A developmental psychologist and gerontologist, German-born **Paul B. Baltes** (page 50) is director at the Max Planck Institute for Human Development and a professor of psychology at Berlin's Free University. He has spent considerable time in the United States, as a professor at Penn State University (1974–80) and as a fellow at the Center for Advanced Study in the Behavioral Sciences, Stanford, California (1977–78 and 1990–91). Early on in his career, Baltes became convinced that the topic of intelligence lay at the heart of psychology. This, combined with his belief in individual development as a lifelong process, has contributed to his continuing interest in the aging mind. Baltes's central belief is that despite the limitations in physical vitality that inevitably come with old age, this last stage of life holds more potential than is generally recognized.

From the moment he first peered into a hive of honey bees, **Gene E. Robinson** (page 40) was intrigued by the order that was apparent despite the seemingly frenzied level of activity. At the time, he was a volunteer on a kibbutz in Israel, during a break from schooling. Now, nineteen years and three degrees later, Robinson is an assistant professor of entomology at the University of Illinois, Urbana-Champaign. Much of his work, using physiology and genetics, is aimed at understanding how the activities of individual worker bees are integrated into the functioning of the colony as a whole. He has also begun to investigate the neurochemical and neuroanatomical basis of behavioral development in honey bees.

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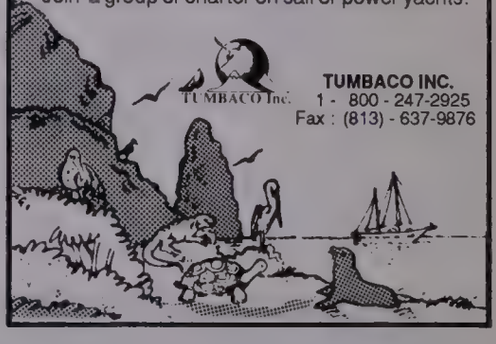

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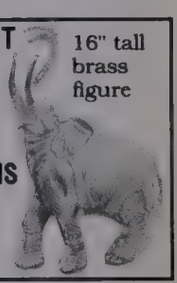

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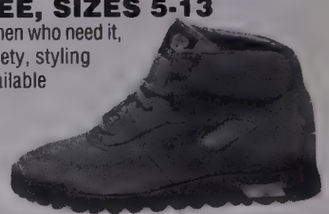

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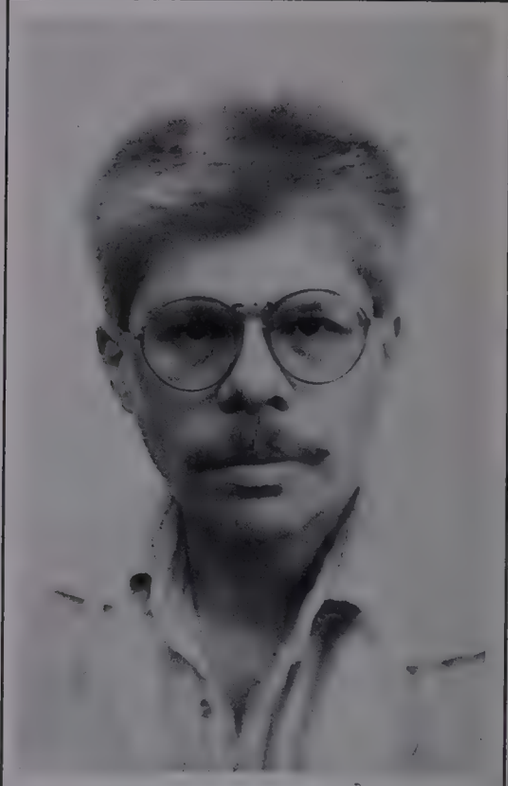
Graham Bell (page 36) reports that he was inspired to look at the topic of fission and aging when, while browsing in the library, he came across an article by L. L. Woodruff entitled "20,000 Generations of *Paramecium*." (Bell lists "reading Shakespeare" as a high-ranking avocation; with such stiff competition, Woodruff's article must have been inspiring indeed.) Bell is Molson Professor of Genetics at McGill University in Montreal. Most of his research takes place in the laboratory and includes experiments on the mechanisms of evolution in *Chlamydomonas*. He is also interested in the physical and biotic properties of natural forest environments.

When photographer **Marilyn Kazmers** (page 78) stopped to focus her camera on a fox den, she didn't notice a male red fox emerging from another hole. "He sat a few yards above me on the hill, surveying the tundra. Avoiding eye contact and seeming to ignore my presence, the fox demonstrated his nonchalance with a yawn. As I quietly moved away, however, he rose, moved to the spot I had just departed, scent marked, and trotted off down the hill." Leaving behind a career in business, Kazmers now devotes her time exclusively to free-lance photography, her primary interest being underwater subjects. Based in Okemos, Michigan, she travels widely and has spent part of the past two years in Alaska and along the northwest coast of Canada and the United States, documenting the scenery and wildlife, as well as remnants of native culture. Capturing images such as the yawning fox featured in this month's "Natural Moment" rewarded three weeks of camping in the cold rain of Denali National Park, contending with gray skies and washed-out roads. The photograph was taken with a Nikon F4 and 300mm Nikkor lens from a distance of fifteen to twenty feet.



Much of the work reported on in **Robert G. Allen**'s article (page 28) was carried out while he was a postdoctoral fellow at Southern Methodist University in Dallas and a research associate at the Laboratory of Investigative Dermatology at the Rockefeller University in New York City. While at Rockefeller, he was also part of a research team that used molecular technology to determine the location of the defective gene responsible for Fanconi's anemia, a disease that causes bone marrow failure and leukemia in children. Allen recently took up a position as an assistant professor at the Medical College of Pennsylvania, in Philadelphia. His research there will involve a project to isolate genes that are activated by changes in oxygen concentration. This mechanism of control appears to be important in both development and aging.

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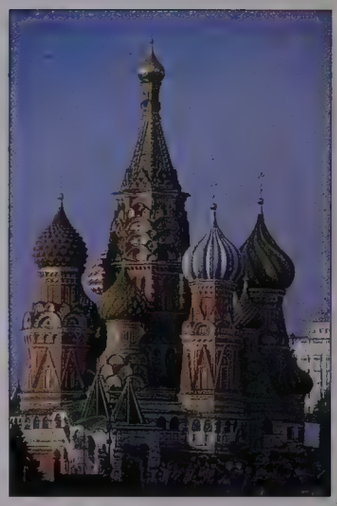

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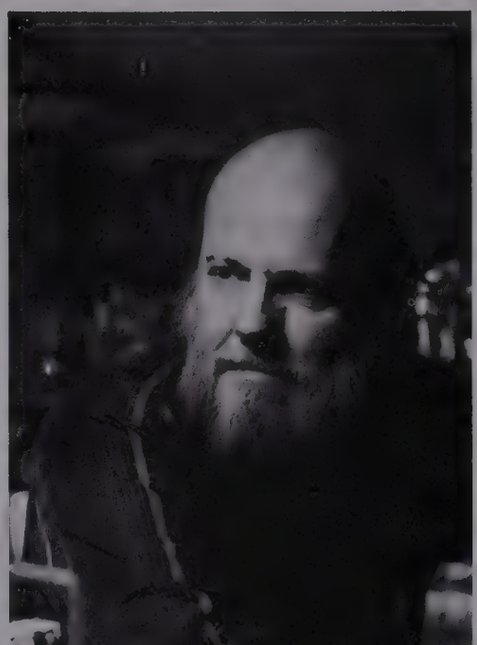
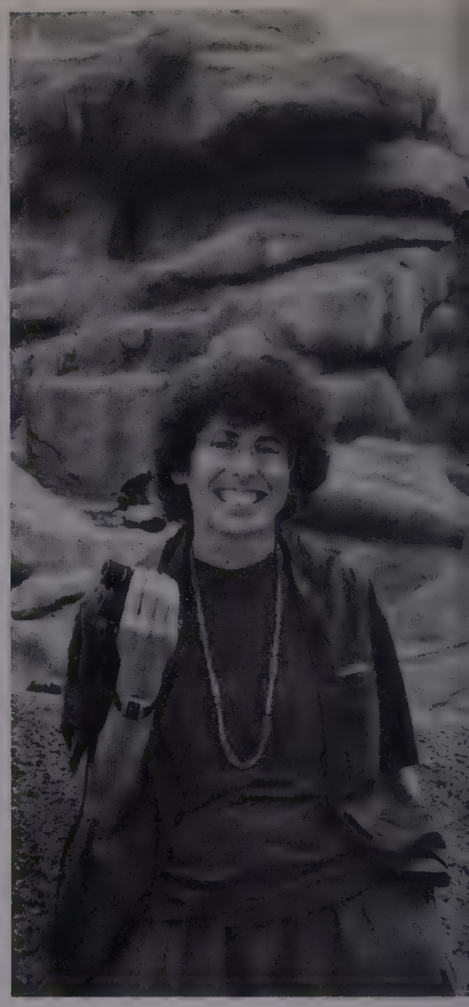
A professor of zoology at the University of Georgia, **J. Whitfield Gibbons** (page 32) conducts most of his field research at the Savannah River Ecology Laboratory in South Carolina. He has been studying the life history and ecology of turtles there for twenty-five years. Gibbons's other main turtling ground is the Kellogg Biological Station in Michigan, where he has been following the fates of turtles for the past twenty-eight years. Many aspects of turtle aging have become clear, but much remains to be learned. For example, despite their impressive longevity, turtles don't live forever, and Gibbons hopes to one day understand what does kill off old turtles and whether they do, in fact, show signs of aging if they grow old enough. When not tracking turtles, alligators, and other reptiles, Gibbons enjoys writing about them in magazine articles, newspaper columns, and short stories.

Caleb Ellicott Finch (page 44) is Arco and William F. Kieschnick Professor in the Neurobiology of Aging at the University of Southern California, Los Angeles. His interest in aging is wide ranging and has included work in the field (together with Robert Ricklefs and Ian Nisbet, on the endocrinology of aging in marine birds) and in the laboratory (primarily on laboratory rodents and postmortem brain samples). His scholarly work involves extensive study of the scientific literature on aging of virtually every taxonomic group one could think of. Finch's present research is on genomic expression in mammalian development and aging, with an emphasis on the role of aging in Alzheimer's disease. In the future, he will also explore the molecular genetics that lie behind differences in aging among species.





Jeanne Altmann (page 48) is a profes sor of ecology and evolution at the Uni versity of Chicago and a research cura tor at the Chicago Zoological Society' Brookfield Zoo. After being raised in th suburbs, she fled to city life in Chicag and fieldwork in East Africa. She nov alternates these with sojourns on a farn where her hobby is relaxing in the ho tub. Her professional interests focus o nonexperimental research methodology life-history aspects of family structure parental care, and development, particu larly in nonhuman primates; and behav ioral and educational problems in con servation.

Additional Reading

For more information on aging in humans and other animals, our authors suggest the following books.

Longevity, Senescence, and the Genome, by Caleb E. Finch. *University of Chicago Press, 1991.*

The Evolution of Aging, by Michael R. Rose. *Oxford University Press, 1991.*

Biology of Aging, by Robert Arking. *Prentice Hall, 1991.*

Successful Aging, edited by P. B. Baltes and M. M. Baltes. *Cambridge University Press, 1990.*

Sex and Death in Protozoa, by Graham Bell. *Cambridge University Press, 1989.*

Insect Aging, edited by K. G. Collatz and R. S. Sohal. *Springer-Verlag, 1986.*

Retardation of Aging and Disease by Dietary Restriction, by Richard Weindruch and Roy L. Walford. *Charles C. Thomas, 1988.*

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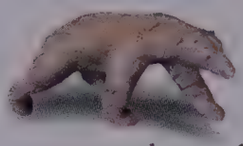

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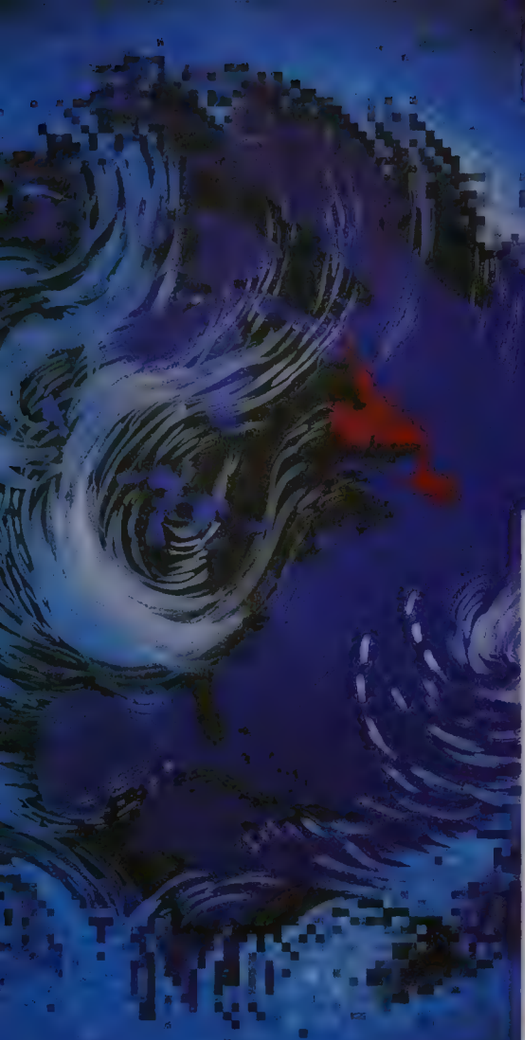

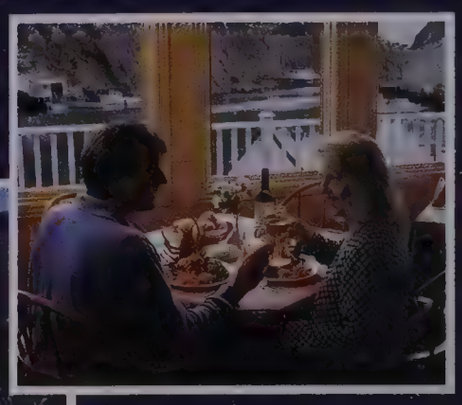

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NATURAL HISTORY (ISSN 0028-0712) is published monthly by the American Museum of Natural History, Central Park West at 79th Street, New York, N.Y. 10024. Subscriptions: $25.00 a year. In Canada and all other countries: $34.00 a year. Second-class postage paid at New York, N.Y., and at additional mailing offices. Copyright © 1992 by American Museum of Natural History. All rights reserved. No part of this periodical may be reproduced without written consent of *Natural History*. Send subscription orders and undeliverable copies to the address below. Membership and subscription information: Write to address below or call (800) 234-5252 if urgent. POSTMASTER: Send address changes to Natural History, Post Office Box 5000, Harlan, IA 51537-5000.

Dinosaurs in the Haystack

Does it matter whether a world ends with a bang or a whimper?

by Stephen Jay Gould

The fashion industry thrives on our need to proclaim an identity from our most personal space. For academics, who by stereotype (although not always in actuality) scorn the sartorial mode, office doors serve the same function. Professorial entranceways are festooned with testimonies of deepest beliefs and strongest commitments. We may, as a profession, have a deserved reputation for lengthy and tendentious proclamation, but our office doors feature the gentler approach of humor or epigram. The staples of this genre are cartoons (with Gary Larson as the unchallenged *número uno* for scientific doors) and quotations from gurus of the profession.

Somehow, I have never been able to put someone else's cleverness so close to my soul. I wear white T-shirts, and although I wrote the preface to one of Gary Larson's *Far Side* collections, I would never identify my portal with his brilliance. But I do have a favorite quotation—one fit for shouting from the housetops (if not for inscription on the doorway).

My favorite line, from Darwin of course, requires a little explication. Geology, in the late eighteenth century, had been deluged with a rash of comprehensive, but mostly fatuous, "theories of the earth"—extended speculations about everything, generated largely from armchairs. When the Geological Society of London was inaugurated in the early nineteenth century, the founding members overreacted to this admitted blight by essentially banning all theoretical discussion from their proceedings. Geologists, they ruled, should first establish the facts of our planet's history by direct observation, and then, at some future time when the bulk of accumulated information becomes sufficiently dense, move to theories and explanations.

Darwin, who had such a keen understanding of fruitful procedure in science, knew in his guts that theory and observation are Siamese twins. They are intertwined and continually interacting; one cannot perform first while the other waits in the wings. In a letter to Henry Fawcett in 1861, Darwin reflected on the false view of earlier geologists. In so doing, he outlined his own conception of proper scientific procedure in the best one-liner ever penned. The last sentence is indelibly impressed on the portal to my psyche.

> About thirty years ago there was much talk that geologists ought only to observe and not theorize; and I well remember someone saying that at this rate a man might as well go into a gravel-pit and count the pebbles and describe the colors. How odd it is that anyone should not see that all observation must be for or against some view if it is to be of any service!

The point should be obvious. Immanuel Kant, in a famous quip, said that concepts without percepts are empty, whereas percepts without concepts are blind. The world is so complex; why should we strive to comprehend with only half our tools? Let our minds play with ideas, let our senses gather information, and let the rich interaction proceed as it must (for the mind processes what the senses gather, while a disembodied brain, devoid of all external input, would be a sorry instrument indeed).

Yet scientists have a peculiar stake in emphasizing fact over theory, percept

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over concept—and Darwin wrote to Fawcett to counteract this odd but effective mythology. Scientists often strive for special status by claiming a unique form of objectivity inherent in a supposedly universal procedure called *the* scientific method. We attain this objectivity by clearing the mind of all preconception and then simply seeing, in a pure and unfettered way, what nature presents. This image may be beguiling, but the claim is chimerical and ultimately haughty and divisive. For the myth of pure perception raises scientists to a pinnacle above all other struggling intellectuals, who must remain mired in constraints of culture and psyche.

But followers of the myth are ultimately hurt and limited, for the immense complexity of the world cannot be grasped or ordered without concepts. "All observation must be for or against some view if it is to be of any service!" Objectivity is not an unobtainable emptying of mind but a willingness to abandon a set of preferences when the world seems to work in a contrary way.

This Darwinian theme of necessary interaction between theory and observation gains strong support from a scientist's standard "take" on the value of original theories. Sure, we love them for the usual "big" reasons—because they change our interpretation of the world and lead us to order things differently. But ask any practicing scientist, and you will probably get a different primary answer, for we are hung up on the details and rhythms of our daily work, and we don't think about ultimates very often. We love original theories because they suggest new, different, and tractable ways to make observations. By posing new questions, they expand our range of ordinary activity. Theories drive us to seek new information that only becomes relevant as data either for or against a hot idea. Data adjudicate theory, but theory also drives and inspires data. Both Kant and Darwin were right.

I bring up this personal favorite among quotations because my profession of paleontology has recently witnessed a fine example of theory confirmed by data that no one ever thought of collecting before the theory itself demanded such a test. (Please note the fundamental difference between demanding a test and guaranteeing the result. The test might just as well have failed, thus dooming the theory. Good theories invite a challenge but do not bias the outcome. In this case, the test succeeded twice, and the theory has gained strength.) Ironically, this particular new theory would have been anathema to Darwin himself, but such a genial and generous man would, I am sure, have gladly taken his immediate lumps in exchange for such a fine example of his generality about theory and observation, and for the excitement of any idea so full of juicy implications.

We have known since the dawn of modern paleontology that short stretches of geological time feature extinctions of substantial percentages of life—up to 96 percent of marine invertebrate species in the granddaddy of all such events, the late Permian debacle some 225 million years ago. These "mass extinctions" were originally explained, in a literal and commonsense sort of way, as products of catastrophic events, and therefore truly sudden. As Darwin's idea of gradualistic evolution replaced this earlier catastrophism, paleontologists sought to mitigate the evidence of mass dying with a reading more congenial to Darwin's preference for slow and steady. The periods of enhanced extinction were not denied—how could they be in the face of such evidence?—but they were reinterpreted as more spread out in time and less intense in effect: in short, as intensifications of ordinary processes, rather than impositions of true and rare catastrophes.

In the *Origin of Species* (1859), Darwin rejected "the old notion of all the inhabitants of the earth having been swept away at successive periods by catastrophes," as well he might, given the extreme view of total annihilation, with its antievolutionary implication of a new creation to start life again. But Darwin's preferences for gradualism were also extreme and false:

> We have every reason to believe . . . that species and groups of species gradually disappear, one after another, first from one spot, then from another, and finally from the world.

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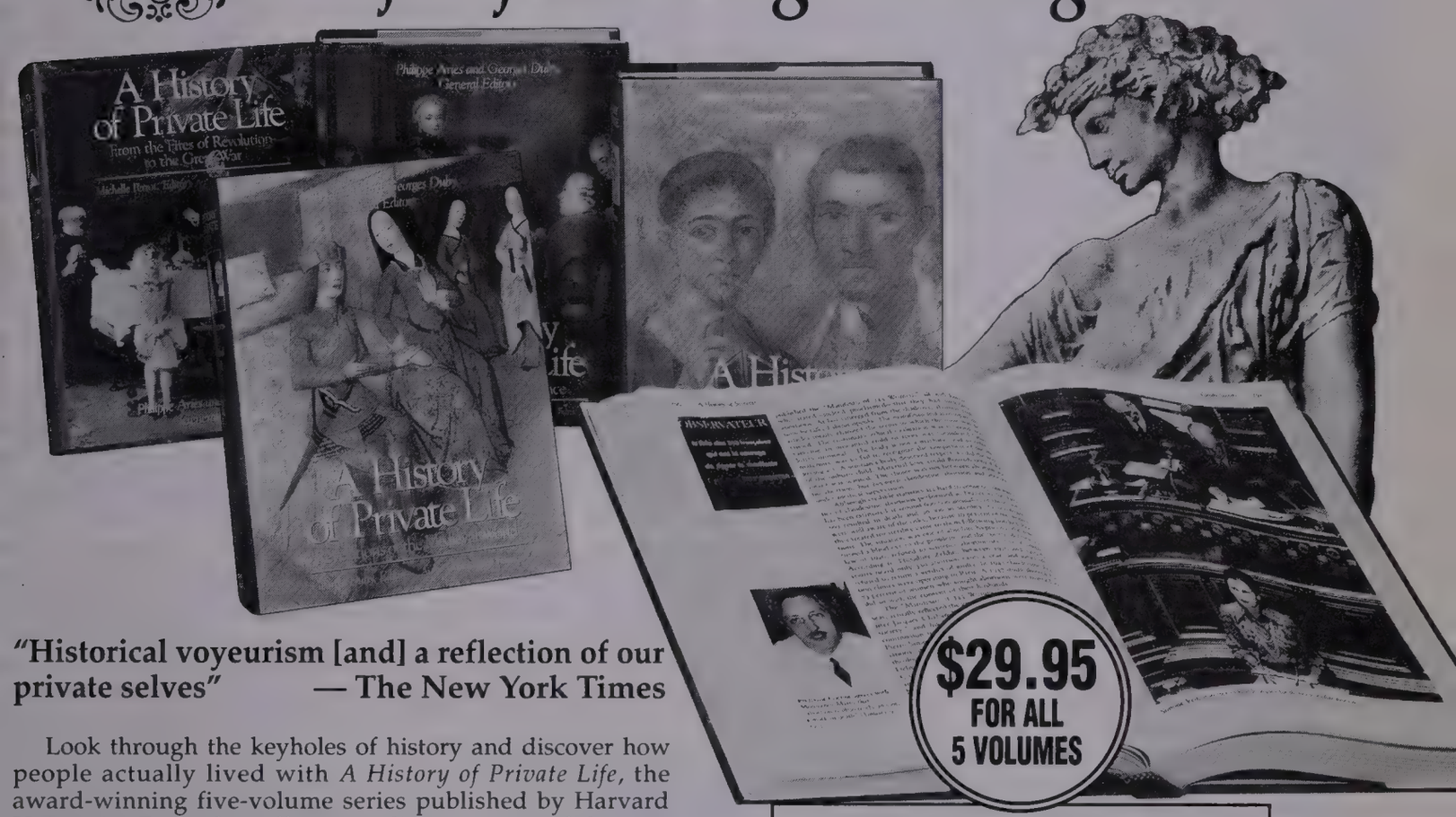

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Darwin himself had to admit the apparent exceptions:

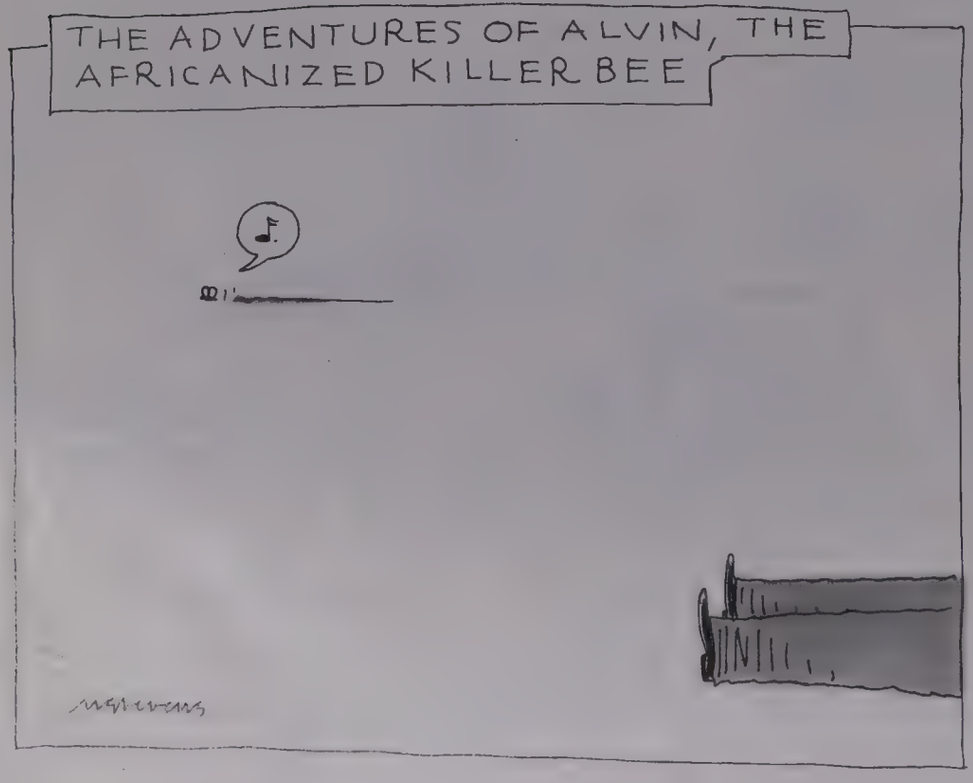
> In some cases, however, the extermination of whole groups of beings, as of the ammonites towards the close of the secondary period, has been wonderfully sudden.

We now come to the central irony that inspired this essay. So long as Darwin's gradualistic view of mass extinction prevailed, paleontological data, read literally, could not refute the basic premise of gradualism—the "spreading out" of extinctions over a good stretch of time before the boundary, rather than a sharp concentration of disappearances right at the boundary itself. For the geological record is highly imperfect and only a tiny fraction of living creatures ever become fossils. As a consequence of this imperfection, even a truly sudden and simultaneous extinction of numerous species will be recorded as a more gradual decline in the fossil record. This claim may sound paradoxical, but consider the following argument and circumstance.

Some species are very common and easily preserved as fossils; we may, on average, find specimens in every inch of strata. But other species will be rare and poorly preserved, and we might encounter their fossils only once every 100 feet or so. Now suppose that all these species died suddenly at the same time, after 400 feet of sediment had been deposited in an ocean basin. Would we expect to find the most direct evidence for mass extinction—that is, fossils of all species through all 400 feet of strata right up to the very top of the sequence? Of course not.

Common species would pervade the strata to the top, for we expect to find their fossils in every inch of sediment. But even if rare species live right to the end, they only contribute a fossil every 100 feet or so. In other words, a rare species may have lived through 400 feet, but its last fossil may be entombed 100 feet below the upper boundary. We might then falsely assume that this rare species died out after three-fourths of the total time had elapsed.

Generalizing this argument, we may assert that the rarer the species, the more likely that its last fossil appears in older sediments even if the species actually lived to the upper boundary. If all species died at once, we will still find a graded and apparently gradualistic sequence of disappearances, the rare species going first and the common forms persisting as fossils right to the upper boundary. This phenomenon—a classic example of the old principle that things are seldom what they seem and that literal appearances often obscure reality—even has a name: the Signor-Lipps effect, to honor two of my paleontological buddies, Phil Signor and Jere Lipps, who first worked out the mathematical details of how a literal petering-out might represent a truly sudden and simultaneous disappearance.



We can now sense the power of Darwin's argument about needing theories to guide observations. We say, in our mythology, that old theories die when new observations derail them. But too often, indeed I would say usually, theories act as straitjackets to channel observations toward their support and to forestall data that might refute them. Such theories cannot be rejected from within, for we will not conceptualize the potentially refuting observations. If we accept Darwinian gradualism in mass extinctions, and therefore never realize that a graded series of fossil disappearances might, by the Signor-Lipps effect, actually represent a sudden wipeout, how will we ever come to consider the catastrophic alternative? For we will be smugly satisfied that we have "hard" data to prove gradualistic decline in species numbers.

New theories are to this conceptual block what Harry Houdini was to straitjackets. We escape by importing a new theory and by making the different kinds of observations that any novel outlook must suggest. For "all observation must be for or against some view," and a new view can therefore engender original observations. I am not making an abstract point or waving arms for my favorite Darwinian motto. Recently, two lovely examples with the same message have been published by a pair of my closest colleagues: studies of ammonites and dinosaurs through the last great extinction.

Anyone who keeps up with press reports on hot items in science knows that a new catastrophic theory of mass extinction has illuminated the paleontological world (and graced the cover of *Time* magazine) during the past decade. In 1980, the father–son (and physicist–geologist) team of Luis and Walter Alvarez published, with colleagues Frank Asaro and Helen Michel, their argument and supporting data for extraterrestrial impact of an asteroid or comet as the cause of the Cretaceous-Tertiary extinction, most recent of the great mass dyings and the time of extinction for dinosaurs along with some 50 percent of marine invertebrate species.

This proposal unleashed a furious debate that cannot be summarized in a page, much less an entire essay, or even a book. Yet I think it fair to say that the idea of extraterrestrial impact has weathered this storm splendidly and continually increased in strength and supporting evidence. At this point, very few scientists deny that an impact occurred, and debate has largely shifted to whether the impact caused the extinction in toto (or only acted as a *coup de grâce* for a process already in the works), and whether other mass ex-

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tinctions may have had a similar cause.

New forms of supporting evidence are reported on a monthly basis in almost every issue of major journals. In the past few weeks we have learned about minute diamonds in sediments from the impact boundary. Diamonds are a form of pure carbon produced under immense pressures that impacts, and no other known process active at the earth's surface, can generate. This discovery may represent the literal fulfillment of that Beatles' classic about psychic hallucinations, "Lucy in the Sky with Diamonds" (and its obvious acronym). Lucy is, literally, light—and the impact was quite a blast. Moreover, the smoking gun may now have been located as a massive crater in the Gulf of Mexico, off the Yucatán Peninsula.

Paleontologists, with very few exceptions, reacted negatively, to say the least, and Luis Alvarez, a virtual model for the stereotype of the self-assured physicist, was fit to be tied. Luis, in retrospect, was also mostly right, so I forgive his fulminations against my profession. I, if I may toot my horn, was among his few initial supporters, but not for the right reason of better insight into the evidence. Catastrophic extinction simply matched my idiosyncratic preference for rapidity, born of the debate over punctuated equilibrium (see my essay of August 1991). After all, my colleagues had been supporting Darwinian gradualism for a century, and the fossil record, read literally, seemed to indicate a petering-out of most groups before the boundary. How could an impact cause the extinction if most species were already dead? But the extraterrestrial impact theory soon proved its mettle in the most sublime way of all: by Darwin's criterion of provoking new observations that no one had thought of making under old views. The theory, in short, engendered its own test and broke the straitjacket of previous certainty.

My colleagues may have disliked the Alvarez hypothesis with unconcealed vigor, but we are an honorable lot, and as debate intensified and favorable evidence accumulated, paleontologists had to take another look at their previous convictions. Many new kinds of observations can be made, but let us focus on the simplest, most obvious, and most literal example. In the light of new prestige for impact and sudden termination, the Signor-Lipps argument began to sink in, and paleontologists realized that catastrophic wipeouts might be recorded as gradual declines in the fossil record.

How then to break the impasse of this indecisive broad appearance of petering-out? Many procedures, some rather subtle and mathematical, have been proposed and pursued, but why not start with the most direct approach. If rare species actually lived right to the impact boundary but have not yet been recorded from the uppermost strata, why not look a whole lot harder. The obvious analogy to the usual cliché suggests itself. If I search for a single needle in the haystack by sampling ten handfuls of hay, I have very little chance of locating it. But if I take apart the stack, straw by straw, I will recover the needle. Similarly, if I really search every inch of sediment in every known locality, I might eventually find even the rarest species right near the boundary—if it truly survived.

This all seems rather obvious. I cannot possibly argue that such an approach was unthinkable before the Alvarez hypothesis. I cannot claim that conceptual blinders of gradualism made it impossible even to imagine pulling apart the haystack rather than sampling it. But this example becomes so appealing precisely through its entirely pedestrian character. I could cite many fancy cases of original theories that open entirely new worlds of observation: think of Galileo's telescope and all the impossible phenomena thus revealed.

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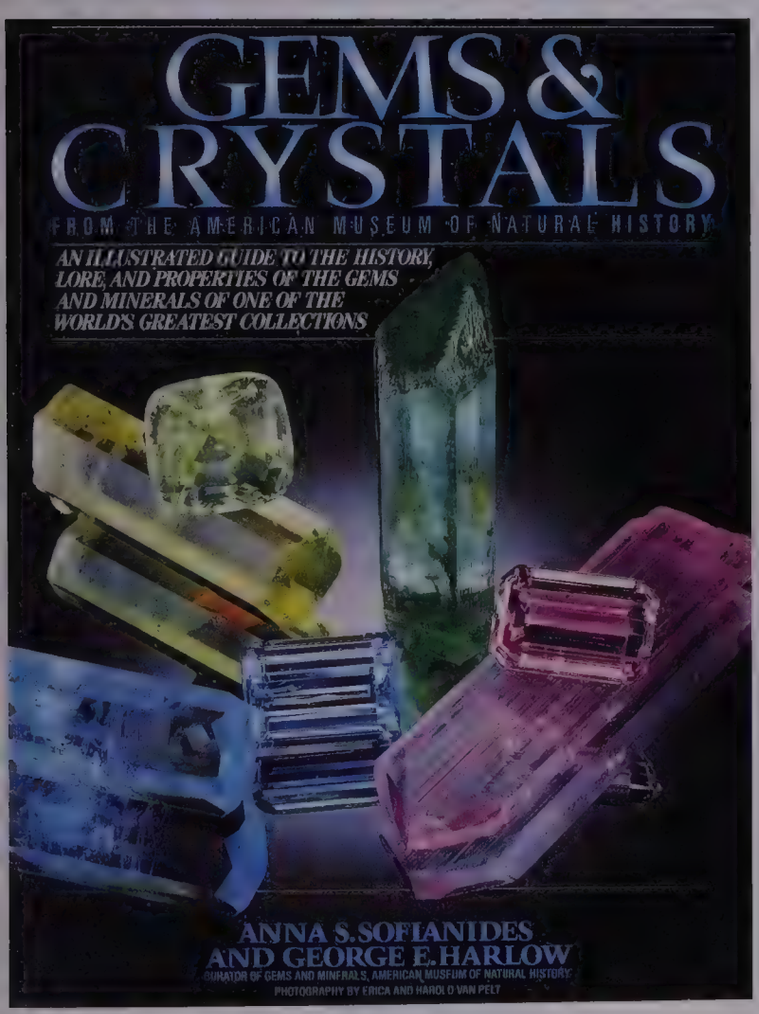
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In this case, the Alvarez theory suggested little more than hard work.

So why wasn't the effort expended before? Paleontologists are an industrious lot; we have faults aplenty, but laziness in the field is not among them. We do love to find fossils; this is why most of us entered the profession in the first place. We didn't scrutinize every inch of sediment for the most basic of all scientific reasons. Life is short and the world is immense; you can't spend your career on a single cliff face. The essence of science is intelligent sampling, not sitting in a single place and trying to get every last one. Under Darwinian gradualism, intelligent sampling followed the usual handful-from-the-haystack method. The results obtained matched the expectations of theory, and conceptual satisfaction (in retrospect, one might say "sloth") set in. No impetus existed for the much more laborious dismember-the-entire-haystack method, a quite unusual approach in science. We could have worked this way, but we didn't because we had no reason to do so. The Alvarez theory made this unusual approach necessary. It forced us to look in a different way. "All observation must be for or against some view if it is to be of any service!"

Consider two premier examples—the best-known marine terrestrial groups to disappear in the Cretaceous-Tertiary extinction: ammonites and dinosaurs. Both had been prominently cited as support for gradual extinction toward the boundary. In each case, the Alvarez hypothesis inspired a closer look via the dismember-the-haystack method, and in each case, this greater scrutiny yielded evidence of persistence to the boundary and potentially catastrophic death.

Ammonites are cephalopods (mollusks classified in the same group as squids and octopuses) with coiled external shells closely resembling those of their nearest living relative, the chambered nautilus. They were a prominent, and often dominant, group of marine predators, and their beautiful fossil shells have always been prized by collectors. They arose in mid-Paleozoic times and had nearly become extinct twice before—in two other mass dyings at the end of the Permian and of the Triassic periods. But a lineage or two had scraped by each time. At the Cretaceous-Tertiary boundary, however, all lineages succumbed, and to cite Wordsworth from another context, there "passed away a glory from the earth."

My friend and colleague Peter Ward, paleontologist from the University of Washington, is one of the world's experts on ammonite extinction; a vigorous, committed man who adores fieldwork and could never be accused of laziness on the outcrop. Peter didn't care much for Alvarez at first, largely because his ammonites seemed to peter out and disappear entirely some thirty feet below the boundary at his favorite site, the cliffs of Zumaya on the Bay of Biscay in Spain. In 1983, Peter wrote an article for *Scientific American* entitled "The Extinction of the Ammonites." He stated his opposition to the Alvarez theory, then so new and controversial, at least as an explanation for the death of ammonites:

> The fossil record suggests, however, that the extinction of the ammonites was a consequence not of this catastrophe but of sweeping changes in the late Cretaceous marine ecosystem. . . . Studies of the fossils from the stratigraphic sections at Zumaya in Spain suggest they became extinct long before the proposed impact of the meteoritic body.

But Peter, as one of the smartest and most honorable men I know, also acknowledged the limits of such "negative evidence." A conclusion based on *not* finding something has the great virtue of unambiguous potential refutation. Peter wrote: "This evidence is negative and could be overturned by the finding of a single new ammonite specimen."

Without the impact hypothesis, Peter would have had no impetus to search these upper thirty feet of section with any more care. Extinctions were supposed to be gradual, and thirty feet of missing ammonites made perfect sense, so why look any further. But the impact hypothesis, with its clear prediction of ammonite survival right up to the boundary itself, demanded more intense scrutiny of the thirty-foot haystack. In 1986, Peter was still touting sequential disappearance: "Ammonites . . . appear to have become extinct in this basin well before the K/T [Cretaceous-Teritary] boundary, supporting a more gradualistic view of the K/T extinctions" (*Palaios*, vol. 1, pp. 87–92).

But Peter and his field partners, inspired by Alvarez (if only by a hope of disproving the impact hypothesis), worked on through the haystack: "The remaining part of the Cretaceous section was well exposed and vigorously searched and quarried." Finally, later in 1986, they found a single specimen just three feet below the boundary. It was crushed, and they couldn't tell for certain whether it was an ammonite or a nautiloid, but this specimen did proclaim a need for even more careful search. (Since nautiloids obviously survived the extinction—the chambered nautilus still lives today—such a fossil right at the boundary would occasion no surprise.)

Peter started a much more intense search in 1987, and the ammonites began to turn up—mostly lousy specimens and very rare, but clearly present right up to

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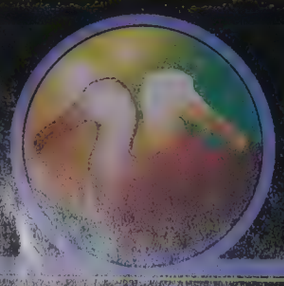

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the boundary. Peter writes in a book just published:

> Finally, on a rainy day, I found a fragment of an ammonite within inches of the clay layer marking the boundary. Slowly, over the years, several more were found in the highest levels of Cretaceous strata at Zumaya. Ammonites appeared to have been present for Armageddon after all.

Peter then took the obvious next step: look elsewhere. Zumaya contained ammonites right up to the end, but not copiously, perhaps for reasons of local habitat rather than global abundance. Peter had looked in sections west of Zumaya and found no latest Cretaceous ammonites (another reason for his earlier acceptance of gradual extinction). But now, he extended his fieldwork to the east, toward the border of Spain and France. (Again, these eastern sections were known and had always been available for study, but Peter needed the impetus of Alvarez to ask the right questions and to develop a need for making these further observations.) Peter studied two new sections, at Hendaye on the Spanish-French border and right on the yuppie beaches of Biarritz in France. He found an abundance of ammonites just below the boundary line of the great extinction. He writes in his new book:

> After my experience at Zumaya, where years of searching yielded only the slightest evidence . . . near the Cretaceous-Tertiary boundary, I was overjoyed to find a source of ammonites within the last meter of Cretaceous rock during the first hour at Hendaye.

We professionals may care more about ammonites, but dinosaurs fire the popular imagination. No argument against Alvarez has therefore been more prominent, or more persuasive, than the persistent claim by most (but not all) dinosaur specialists that the great beasts, with the possible exception of a straggler or two, were gone long before the supposed impact.

I well remember the dinosaur men advancing their supposed smoking gun of a "three-meter gap"—the barren strata between the last-known dinosaur bone and the impact boundary. And I recall Luis Alvarez exploding in rage and with ample justice (for I felt a bit ashamed of my paleontological colleagues and their very bad argument). The last bone, after all, is not the last animal, but rather a sample from which we might be able to estimate the probable later survival of creatures not yet found as fossils. After all, if my colleague throws a thousand bottles overboard and I later pick up one on an island fifty miles away, I do not assume that he only tossed a single bottle. But if I know the time of his throw and the pattern of currents, I might be able to make a rough estimate of how many he originally dropped overboard. The chance of any animal becoming a fossil is surely much smaller than the probability of my finding even one bottle. All science is intelligent inference: excessive literalism is a delusion, not a humble bowing to evidence.

Again, as with Peter Ward and the ammonites, the best empirical approach would order a stop to the shouting and organize a massive effort to dismember the haystack by looking for dinosaur bones in every inch of latest Cretaceous rocks. Peter means "rock" in Latin, so maybe men of this name are predisposed to a paleontological career. Another Peter, my friend and colleague Peter Sheehan of the Milwaukee Public Museum, has been guiding such a project for years. Just last month (I write this essay in December 1991), he published his much awaited results (*see* "Sudden Extinction of the Dinosaurs: Latest Cretaceous, Upper Great Plains, U.S.A.," by P. M. Sheehan, D. E. Fastovsky, R. G. Hoffmann, C. D. Berghaus, and D. L. Gabriel, *Science,* November 8, 1991, pp. 835–39).

Dinosaurs are almost always rarer than marine creatures, and this haystack really has to be pulled apart fragment by fragment and over a broad area. The National Science Foundation and other funding agencies simply do not supply grant money at such a scale for projects that lack experimental glamor, whatever their importance. So Peter (Sheehan this time) availed himself of a wonderful resource that mere ammonites could never command. I will tell this story in his words:

> We co-opted the longstanding volunteer-based "Dig-a-Dinosaur" program at the Milwaukee Public Museum. Sixteen to 25 carefully trained and closely supervised volunteers and 10 to 12 staff members were present during each of 7 two-week field sessions during three summers. The primary objective of each volunteer was to search a predetermined area for all bone visible on the surface. The volunteers were arrayed in "search party" fashion across exposures so that all outcrops were surveyed systematically. Associated with the field parties were geologists whose function was to measure stratigraphic sections and identify facies.

I cannot think of a more efficient and effective way to tackle a geological haystack. Peter's personnel logged 15,000 hours of fieldwork and have provided our first adequate sampling of dinosaur fossils in uppermost Cretaceous rocks. They worked in the Hell Creek Formation in Montana and North Dakota, the classic strata for latest Cretaceous dinosaurs. They studied each environment sepa-

rately, with best evidence available from stream channels and floodplains. They divided the entire section into thirds, with the upper third extending right up to the impact boundary, and asked whether a steady decline occurred through the three units, leaving an impoverished fauna when the asteroid struck. Again, I will let their terse conclusion, summarizing so much intense effort, speak for itself:

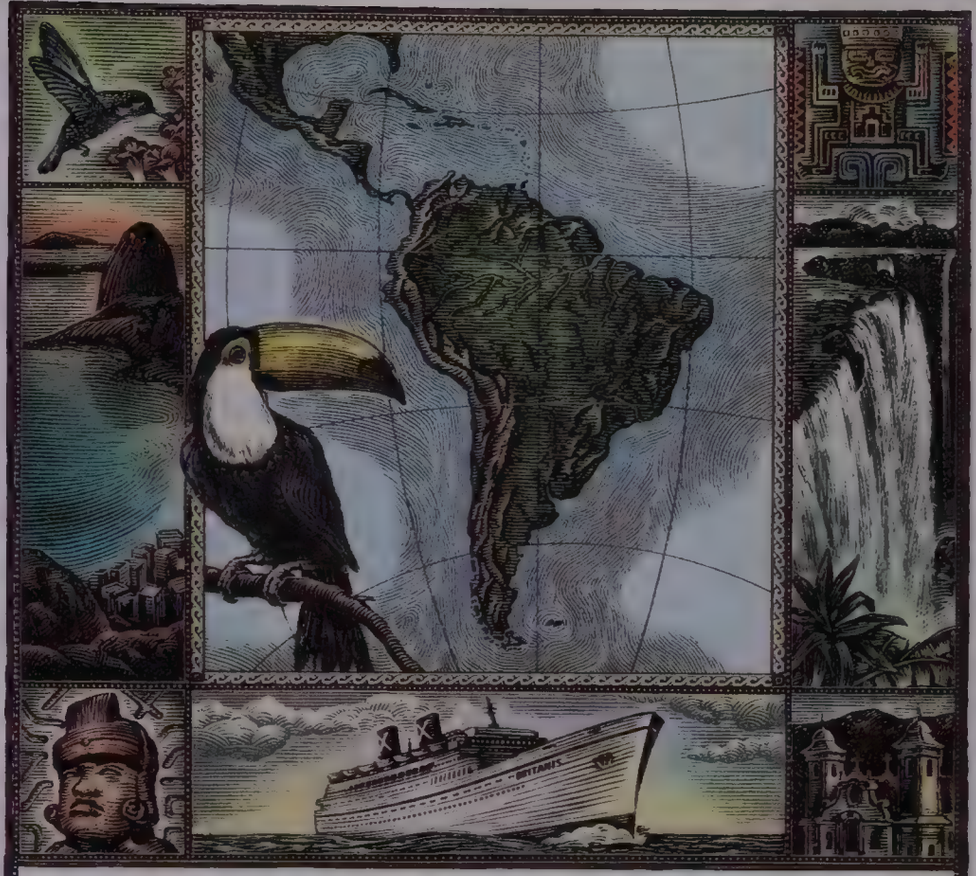
> Because there is no significant change between the lower, middle, and upper thirds of the formation, we reject the hypothesis that the dinosaurian part of the ecosystem was deteriorating during the latest Cretaceous. These findings are consistent with an abrupt extinction scenario.

You can always say, "So what; T. S. Eliot was wrong; some worlds at least end with a bang, not a whimper." But this distinction makes all the difference, for bangs and whimpers have such divergent consequences. Peter Ward sets the right theme in his final statement on the non-necessary demise of ammonites:

> Their history was one of such uncommon and clever adaptation that they should have survived, somewhere, at some great depth. The nautiloids did. It is my prejudice that the ammonites would have, save for a catastrophe that changed the rules 66 million years ago. In their long history they survived everything else the earth threw at them. Perhaps it was something from outer space, not the earth, that finally brought them down.

The true philistine may still say, "So what; no impact and we still have both ammonites and nautiloids. What do I care. I had never even heard of nautiloids before reading this essay." Think about dinosaurs and start caring. No impact to terminate their still-vigorous diversity and perhaps they survive to the present. (Why not? They had done well for more than 100 million years, and the earth has only added another 66 million since then.) If they survive, mammals almost surely remain as small and insignificant as they were during the entire 100 million years of dinosaurian domination. And if mammals stay so small, restricted, and unendowed with consciousness, then surely no humans emerge to proclaim their indifference. Or to name their boys Peter. Or to wonder about the heavens and the earth. Or to ponder the nature of science and the proper interaction between fact and theory. Too dumb to try and too busy scrounging for the next meal and hiding from that nasty *Velociraptor.*

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.



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Charleston Mountains, Nevada

by Robert H. Mohlenbrock

Forty miles northwest of Las Vegas, the lofty Spring Mountains rise out of the Mojave Desert, affording welcome relief from summer swelter and, with snowfalls of fourteen or more feet, ample opportunity for winter recreation. About forty-two miles long and up to twenty-six miles wide, the range is among the most isolated in North America, its nearest neighbor being the Panamint Range of California, 100 miles away. Dominated by 11,910-foot-high Charleston Peak, which lies within Nevada's Toiyabe National Forest, the Spring Mountains are also commonly referred to as the Charleston Mountains.

On the lower slopes, creosote bush and sagebrush, typical plants of the Great Basin, taper down into the Mojave Desert, where a variety of cactuses and other desert-dwelling plants prevail. In the lower foothills, at about 5,000 feet, piñon pines and Utah junipers take over the drier habitats, while from about 6,600 to 8,100 feet ponderosa pines dominate the moist canyons. Bristlecone pines range from as low as 6,900 feet all the way to tree line, which is reached on Charleston Peak at 10,000 feet. At their higher elevations, the bristlecones are joined by limber pines. The treeless summit of Charleston Peak is bordered by small, gnarled specimens of bristlecone pine.

The mountain rock consists of many sedimentary layers of limestone, dolomite, sandstone, shale, and gypsum deposited by the shallow sea that covered the region during the Paleozoic era (590 to 250 million years ago). Geologist Chester Longwell estimated that the deposits are nearly 30,000 feet thick and determined that the mountains themselves were formed about 60 million years ago, when great east–west pressure caused the sedimentary layers to buckle and shear. The violent forces often resulted in older rock formations coming to lie on top of younger ones; this is particularly evident on the south side of Lee Canyon. After a long period of erosion, during which the mountains gradually became lower, renewed pressures thrust some rocks upward and others down.

During the Pleistocene—the epoch of frequent glaciation that lasted from about 1.6 million to 12,000 years ago—southern Nevada was much cooler and moister than it is today. A large lake developed in Las Vegas Valley, and relatives of elephants, camels, and horses lived in the boggy habitat, benefiting from the plant life that must have thrived there. At that time, plant species were able to migrate across the low, wet terrain and colonize the Charleston Mountains.

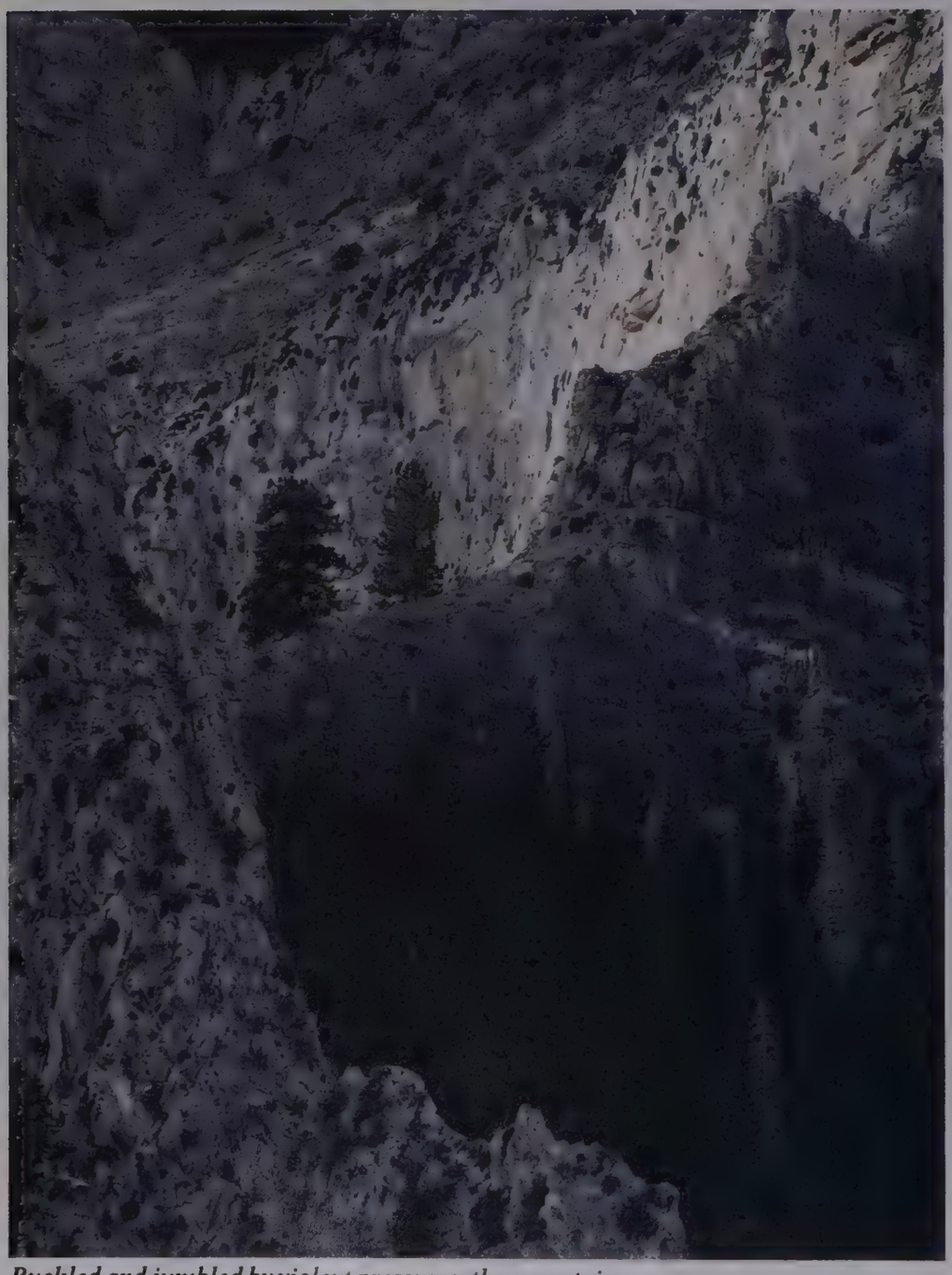
As the Pleistocene ended and the climate became warmer and drier, the lake in Las Vegas Valley gradually disappeared and the Mojave Desert was formed. The plants that had become established in the Charleston Mountains became isolated, sometimes a long distance from their place of origin. Extended isolation, particularly in high mountain areas, provides an opportunity for plants to develop distinctive characteristics or even evolve into separate species.

The plants of the Charleston Mountains were studied by botanist Ira W. Clokey half a century ago. He discovered that approximately twenty kinds of flowering plants are found in this range and nowhere else, although all but one of them has a close relative elsewhere in the western United States. (The exception is Charleston kitten-tails, a plant whose leaves

Scarlet trumpet, above, blooms in the late summer in the Charleston Mountains. Opposite page: The weathered wood of a bristlecone pine.

Photographs by Jay S. Simon

Joe LeMonnier



Buckled and jumbled by violent pressures, the mountains consist of sedimentary layers deposited by an ancient sea.

Charleston Mountains

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closely resemble those of alumroot, a totally unrelated species with which it grows.) Because of their uniqueness, these endemic species are monitored by Toiyabe National Forest botanist Dave Weixelman and regional forest botanist Duane Atwood.

Most of the endemics grow at the higher elevations. Five are found 1,000 feet or so below tree line, where ponderosa pine is the dominant tree. Because environmental conditions in this zone are not as harsh as they are higher up, some of these plants grow quite large. Rough angelica, whose white flower clusters resemble those of Queen Anne's lace, has stems two or more feet tall. The others in this zone are yellow violet, a rosy-flowered sandwort, and two kinds of tiny-leaved milk vetches.

Eight other endemics grow at or above 10,000 feet, either beneath bristlecone pines at the uppermost level of tree growth or above tree line in the high mountain meadows or rocky crevices of Charleston Peak. Rarest of these alpine species is the arching pussy-toes, a dwarf member of the aster family with clustered basal leaves and short, thick heads of white, fuzzy-looking flowers. Although this species spreads by slender runners as well as seeds, it is so uncommon, because of its hostile habitat, that the U.S. Fish and Wildlife Service is considering listing it as endangered.

Other dwarf species are nearly as rare, such as the yellow-headed Charleston tansy; the tiny, yellow-flowered hidden ivesia (a member of the rose family whose summer flowers barely peek out around small limestone pebbles); and the inconspicuous, white-blooming Charleston draba, which is found near natural springs in the high mountains. Prettiest of the alpine rarities is Clokey's catchfly, a delicate plant with a single, large, nodding, rosy pink flower. All provide a pleasant, scientifically interesting, and certainly less expensive change of pace from the glitter of nearby Las Vegas.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.

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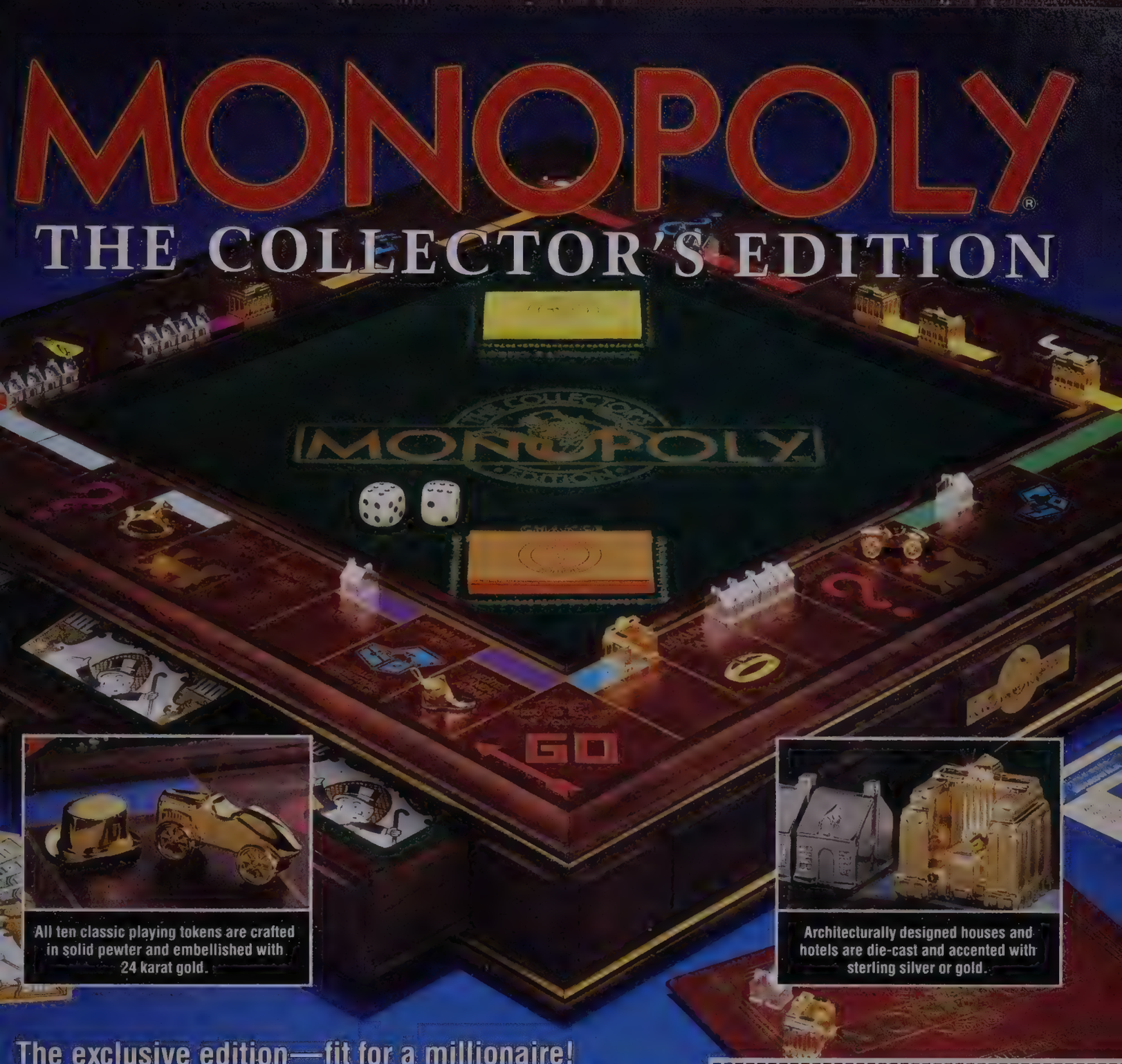

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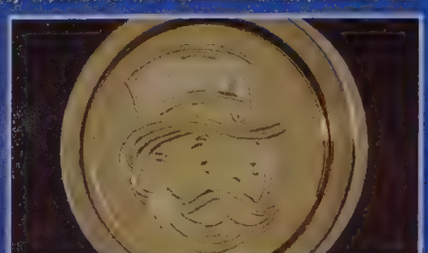

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Echoes of a Lost Colony

Long after the Teotihuacán empire faded from central Mexico, the Maya kept up some of its ways

by Nicholas M. Hellmuth

The construction of Guatemala City has nearly swallowed up the ruins of a regional highland Maya capital called Kaminaljuyú, which flourished from about 2,300 to 1,400 years ago. Based on archeological excavations of its building mounds and tombs, scholars have for years seen Kaminaljuyú as a major entry point in Maya territory for cultural influence from the roughly contemporaneous Mexican city of Teotihuacán, more than 2,000 miles away by trail. They have debated whether Kaminaljuyú represented a subject city or a place of contact for long-distance delegations of merchants and emissaries. Teotihuacán's massive pyramidal temple platforms still testify to their builders' imperial might. But why would Kaminaljuyú, more than other Maya cities, have been the object of these foreigners' attention?

Many have emphasized Kaminaljuyú's proximity to major deposits of obsidian (volcanic glass), the primary domestic tool in a pre-iron era. This traditional answer, I believe, needs to be amended: Kaminaljuyú was also the major Maya city closest to some important Teotihuacán outposts in non-Maya territory. While the imperial city itself lay far to the northwest, the outposts were spread just to the south of Kaminaljuyú, along the steaming coastal plain bordering the Pacific Ocean. Here, during the 1970s, in the region around the town of Tiquisate, bulldozers leveling ancient mounds to create flat fields for farming uncovered many graves and caches. In so doing they unearthed more whole, decorated Teotihuacán-style pottery than has been found in an entire century of excavations at Teotihuacán itself.

This is the ninth article in a series that explores recent findings and interpretations concerning the rise and fall of ancient Maya civilization.

The finds included several hundred censers with elaborate lids, used to burn a sweet-smelling native incense, the sap from copal trees; more than 500 slab-legged, cylindrical tripod vessels decorated with incised or impressed designs; and mold-made figures of gods and warriors. Fired clay molds suggest that these objects were mass-produced based on Teotihuacán prototypes, but the designs have a distinct local style. I was in Guatemala during those years researching Teotihuacán influence on the Maya and was alerted to these discoveries by personnel at the Museo Nacional de Arqueología y Etnología. Nevertheless, this spectacular collection remains little known even twenty years later.

Trade was apparently the main reason

A Maya figure from Copán holds a sacrificial knife. The symbolic decorations on his headdress are central Mexican in origin.

Nicholas M. Hellmuth, F.L.A.A.R.; courtesy of the Instituto Hondureño de Antropología y Historia

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for Teotihuacán's interaction with distant Guatemala. Teotihuacán vied for control of cacao and obsidian (cacao beans may even have served as currency, as they did for the later Aztecs). The area around Tiquisate was prime cacao-growing land and was adjacent to the volcanoes that produced obsidian. Less than 100 miles into the volcanic chain, Maya territory, starting with Kaminaljuyú, began.

Teotihuacán influence on the Maya, whether by direct contact with the capital city or through the filter of the regional outposts near Tiquisate, was selective. Out of a dozen deities, Tlaloc (a rain-fertility and war god) and the feathered serpent are the most consistent exports; out of hundreds of motifs, the butterfly, seashell symbolism, and various markers of conquest warfare are by far the most likely to turn up at Maya sites; and Teotihuacán's architecture is represented by a tiered pyramidal building style and a few decorative elements. While the Teotihuacános may have consciously chosen particular images and styles for export—or the provinces only adopted those they preferred—most likely these recurring motifs were the trappings of the specific segments of Teotihuacán society that interacted with the Maya: merchants, missionaries, warriors, and diplomats.

Tlaloc was the name used by the later Aztecs for an important deity depicted with ringed eyes, who sometimes carried a lightning bolt. Specialists in Teotihuacán art, especially Clara Millon and Esther Pasztory, have found a variety of personalities in the Teotihuacán pantheon with ringed eyes, perhaps representing several distinct deities. These images appear in the ceramic art of the Tiquisate outposts, especially on the pottery used in rituals (to date no stelae or buildings have been unearthed in the area).

Prominent are the butterfly with a Tlaloc face and the warrior with ringed eyes, both of which confirm the god's warlike aspect. (Based on later Aztec practices, art historian Janet Berlo convincingly argues that for the Teotihuacános, butterflies symbolized the souls of warriors who died on the battlefield, where they had been seeking victims for human sacrifice.) Other images of Tlaloc at Tiquisate are more religious than military, showing that Tlaloc was multifaceted, a spiritual leader and war leader combined in one terrifying personality.

Teotihuacán influence on the Maya is confirmed by the discovery of similar ceramic objects and images at Kaminaljuyú and other Maya sites. To get the full picture we also need to include the design of monumental architecture. Between A.D. 350 and 500, the Maya area was inundated by the *talud-tablero* style, favored at the imperial capital for building pyramidal temple platforms. This is a tiered pattern, each tier consisting of a sloping layer topped by a vertical one. More specifically, the face of each tier consists of a plain, sloping wall (*talud*), surmounted by a somewhat overhanging vertical panel (*tablero*), usually a rectangular frame with a decorative inset. The *talud-tablero* construction may be seen at Kaminaljuyú, as well as at the later site of Tikal.

Outposts of Teotihuacán culture existed on Guatemala's Pacific coastal plain near modern Tiquisate.
Joe LeMonnier

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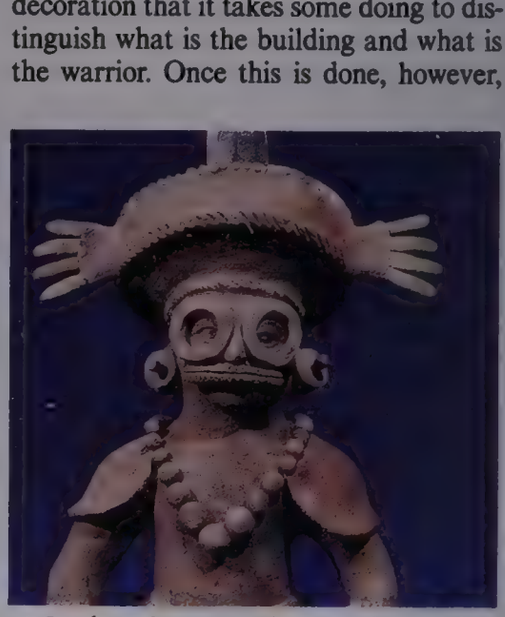
The Maya also adopted step and stepped-fret decorative motifs, two designs popular at Teotihuacán. The *tablero* with repeated step motifs typifies Teotihuacán architecture, while the stepped-fret motif especially characterizes El Tajín, a city near the gulf coast in the Mexican state of Veracruz. Some scholars believe that Oaxaca, the region inhabited by the Zapotec, was the ultimate source of both motifs, but whether or not this is true, they appear to have spread to the Maya through Teotihuacán influence.

Archeologists have not excavated any of the ancient architecture that lies buried beneath the numerous mounds in the Tiquisate area, most of which is probably poorly preserved adobe construction. Local bulldozer and tractor drivers, however, have plowed up several depictions of temples impressed in relief on mold-made pottery. These temple depictions, one on a clay pot and two on the fourteen-inch-high lids of censers, show the decorated top panels of building walls. Since such panels were high up, they were apt to be destroyed when buildings disintegrated. But the pottery depictions of the temples can be translated into realistic perspective drawings, allowing reconstruction of the architectural details. While most archeologists are not trained to render perspective, nowadays user-friendly computer software developed for architects (AutoCAD) will do this automatically for anyone who can join two points together with a straight line. The new, powerful battery-operated computers can do such drawing right at Maya sites.

For example, on one of the incense burner lids, the complete figure of a warrior sits within a Teotihuacán-style temple façade. The piece is so burdened with decoration that it takes some doing to distinguish what is the building and what is the warrior. Once this is done, however,



A Copán ruler wears the ringed eyes of Tlaloc, a rain-fertility and war god.

Nicholas M. Hellmuth, F.L.A.A.R.; courtesy of the Instituto Hondureño de Antropología y Historia

Tiered pyramid construction typifies the imperial capital of Teotihuacán.

Melinda Berge; Bruce Coleman, Inc.

archeologists and art historians can re-create the appearance of the temple.

Did the imperial city of Teotihuacán actually impose its rule on, or coerce allegiance from, Kaminaljuyú and other Maya sites, or did Maya cities voluntarily emulate Teotihuacán ways, perhaps at the behest of chiefly families that profited from the relationship? No one has ever suggested that Mesoamerican religions won converts by friendly persuasion. And the constant brandishing of weapons demonstrates that Teotihuacán won friends and influenced people through power politics and sheer clout. But not a single battle scene shows Teotihuacános strong-arming the Maya. No Teotihuacán character stands atop cowering Maya captives, no Teotihuacán warrior runs a Maya enemy through with a spear.

What we find instead are depictions of Maya who have adapted Teotihuacán trappings for their own conquest warfare. As described by Linda Schele ("The Owl, Shield, and Flint Blade," *Natural History,* November 1991), this symbolism appeared in connection with specific battles in about A.D. 400, as Maya rulers sought to consolidate their power in the Tikal, Uaxactún, and Yaxhá regions.

The effect of the fall of Teotihuacán, in about A.D. 750, provides another indication that Mexican culture was emulated by, rather than imposed upon, the Maya. For unknown reasons, central Teotihuacán authority was destroyed in a relatively sudden manner, although the city itself apparently lasted some additional generations. If Teotihuacán had forcibly controlled Maya sites, we might expect some evidence of a casting-off of alien symbols and ways. But instead we see that the Maya were content to maintain the customs they had incorporated.

Indications are that by A.D. 600, the beginning of the late Classic period, the Maya had made the Mexican elements their own, and direct influence from Teotihuacán had already faded. The most evident features of continued Teotihuacán culture in Maya areas are the *talud-*

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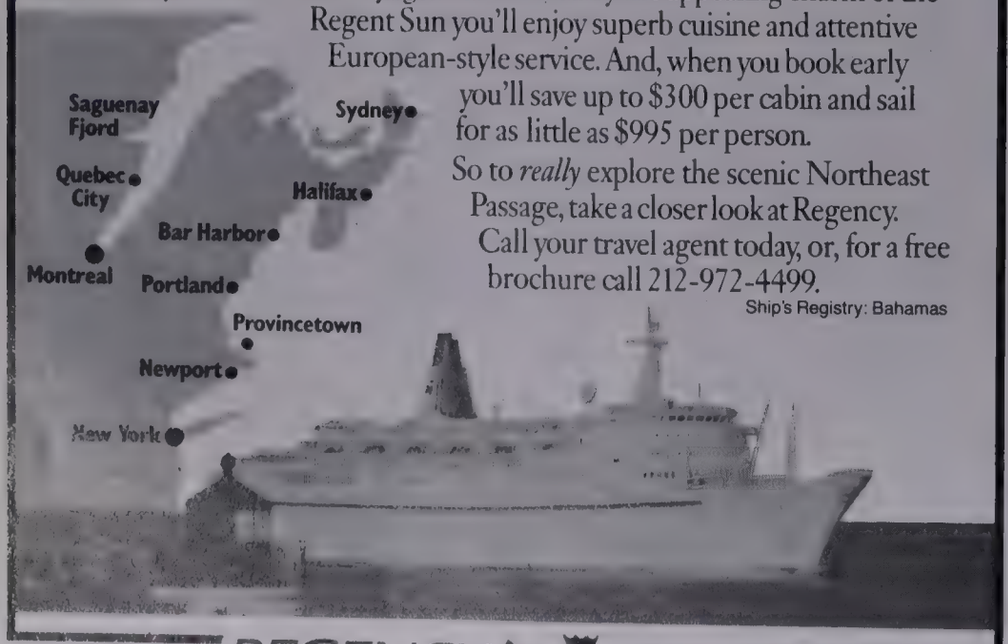

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tablero architecture and the depictions of Tlaloc-like deities, the latter often associated with a trapezoidal interlaced headdress called a year sign. The connection of these elements with militarism seems to account in large part for their perpetuation. The Maya kings continued to be portrayed in association with the symbols of Teotihuacán-style warfare, including a Tlaloc-like face or just the ringed eye.

A typical example of Teotihuacán elements surviving among the late Classic Maya (A.D. 600 to 900) comes from Itzan, an important site in northern Guatemala currently under excavation by Kevin Johnston of Yale University and his Guatemalan colleagues. Although Itzan is thoroughly Maya, one of its several dozen stone stelae pictures its Maya ruler parad-

A detail of pottery found near Tiquisate (photograph and middle drawing) depicts the deity Tlaloc within a temple. Using these architectural clues, artists have reconstructed the temple's design (bottom).

Nicholas M. Hellmuth; courtesy of the Museo Popol-Vuh-Universidad Francisco Marroquin. Drawings by Greg Cestaro and Wendy Giddens.

ing in a full imperial Teotihuacán military outfit. His tail feathers are a residue of Teotihuacán-inspired uniforms introduced centuries earlier. This region was not likely to have been receiving influence from the distant capital city at the time this monument was carved, sometime between A.D. 650 and 800. Far more likely, such a late Classic display of Mexican militarism reflects the presence of an ingrown faction that brandished Teotihuacán symbolism as a badge of power.

The Itzan stela that depicts the Teotihuacán-style ruler is set against a hieroglyphic stairway that was a focus of ritual connected with the sacred Mesoamerican ballgame. The ruler himself wears a complete set of ballgame paraphernalia, including a U-shaped yoke around his waist with an attached *hacha,* a thin stone head used to hit the ball. These too are Mexican elements, believed to have originated in the El Tajín area of Veracruz and spread to the Maya through Teotihuacán influence. At least as many ballgame *hachas* have been found in piedmont Guatemala, the region of which Tiquisate is a part, as in all Veracruz.

An architectural example of Teotihuacán style among the Maya following the fall of the imperial city is Structure 6 at the site of Xkichmook, Yucatán, dated to approximately A.D. 750 to 850. Its colonnettes are typical local Maya features, unknown at Mexican sites. Yet we also find the step and stepped-fret motifs. How did a Maya architect of this time get these Mexican motifs in his sketchbook? As with all artists, his repertoire was inherited from previous generations. Such Teotihuacán influence had been introduced long before not only via Tiquisate into Kaminaljuyú but also probably by means of other land routes.

Between about A.D. 900 and 1100, a new wave of Mexican symbolism swept Maya territory, centering in the northern lowland city of Chichén Itzá. For a long time scholars believed that the Toltecs, whose empire flourished in Tula, fifty miles northwest of Mexico City, actually conquered much of the Yucatán Peninsula. But some now view the Toltec episode as a more local resurgence of Mexican culture. In either case, much of what traditionally has been considered Toltec actually was already firmly and widely implanted among the Maya five centuries earlier, during Teotihuacán times. An example is the presumed Toltec ballgame scene carved into the sides of the Chichén Itzá ball court. This scene, which depicts the sacrifice of a defeated player (probably a captive warrior), had several complete prototypes 500 years earlier in the Tiquisate area, on vases now preserved in Guatemala's Museo Popol Vuh.

Middle America was an international region as early as 2,800 years ago, when Olmec trade routes stretched from southern Mexico through the Tiquisate area and south to Costa Rica. The Teotihuacános had considerable impact at Monte Albán, a Zapotec site in Oaxaca, while there was a settlement of Zapotecs from Monte Albán within the imperial capital. An obscure local Tiquisate deity, Curly Face, is portrayed in Monte Albán on a clay pot, suggesting that the Teotihuacános absorbed some of native Tiquisate culture and spread it back into Mexico. The Maya, too, had an impact: the major deity of their pantheon, known to scholars as God N, appears in a mural at Teotihuacán, and new finds in the murals of Cacaxtla, just a hundred or so miles from Teotihuacán, picture Maya deities (including God L) and Maya warriors with plenty of Teotihuacán features on the side. The international nature of Guatemala more than 1,000 years ago is a glorious chapter of its history that deserves to be remembered and preserved. □

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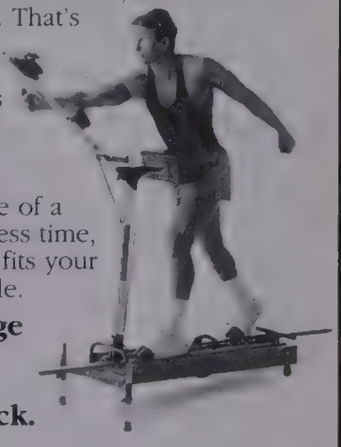

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Life *Au Naturel*

All dogs should be big and black

by Roger L. Welsch

During the Senate confirmation hearings for Justice Clarence Thomas, I missed the denouement of the sexual harassment charges against him because I was still mulling over his initial tangle with natural law, the idea that there are some things so obvious and ubiquitous that no one—no one!—could possibly miss them or misunderstand them. The issue was never settled or even explored with the sort of rigorous (if chaotic) thoroughness that characterizes Congressional investigation. I hope the FBI is still working on the problem.

If it is, agents may want to chat with me, because I have spent almost twenty years thinking about the idea of natural law. It's probably good that someone else put the concept in front of the public before I did, however, because I have been calling it universal truth, which sounds like a church that sells ordinations through the mail or maybe like an expensive perfume—the kind you call *parfum.* This way, the categories are building uniformly: natural history, natural resources, and natural law. Others will certainly fall neatly into place.

I understand the uneasiness some people feel when dealing with laws that are not enacted or even written down but just exist because they are so obvious to everyone. In my experience, what is perfectly obvious to me is not all that obvious to everyone else. Toilet seats should be left up, for example. That should be obvious to anyone who has any sense of order at all. You'd be surprised at the number of people who disagree with that, not to mention the dimensions of their disagreement. All dogs should be big and black, and yet I still see people, unashamed, with little dogs, even white dogs. Then there's New York City—proof positive that not everyone embraces the obvious.

I attribute part of the problem with natural law to the inclusion of trivial precepts—for example, Murphy's Law (anything that can go wrong will go wrong) and all of its permutations, corollaries, and codicils—in listings of natural laws. This detracts from the universality of the other, *really* natural laws (a good argument for my term, *universal law;* it gives the laws in question the scope they deserve).

Or maybe the problem is with the word *law,* which has fallen into considerable disfavor—these days anyway. I know a physicist who collects all sorts of "laws," like the old saw about dropped peanut-buttered toast always falling face down. Well, he knows as well as I do that that is not a natural law. Sometimes, maybe as often as one out of every hundred or so droppings, the toast will fall dry side down. No one knows why. It just happens. Well, if it isn't always true, it isn't a universal law. I'd be willing to go to the Supreme Court with that one.

If there is universal law (or, if you insist, natural law), it has to be so constant and so obvious, there simply are no exceptions. None. Moreover, to my mind, for natural law to be worth the fuss, it also has to be interesting. The sun always comes up in the east (except maybe in late June, when it drifts pretty far north, and about Christmas, when it droops toward Grand Island, or on rainy days when it doesn't come up at all, or when talking with nit-pickers who point out that the sun doesn't "come up" at all), but that tidbit simply is not interesting enough to be a natural law.

Moreover, if you listen to adherents of the natural law idea, you'll quickly learn that they aren't very interested in the natural laws that apply, say, to the inevitability of fruitcakes, preferring to focus almost exclusively on natural laws telling humans what to do. And, for that matter, almost entirely on those laws that tell humans what *not* to do.

I also distrust the judgment of people who claim they have nailed down a couple of hundred natural laws. I think natural laws are few and far between and are usually delivered not by angels but by unlikely, maybe even unselfconscious messengers. These messengers are likely to be surprised when it is called to their attention that they have just discovered or stated or illustrated a natural law.

For example, I was once sitting in the Golden Nugget Tavern on the main street of Cody, Wyoming, eating lunch. A bartender, who had paid little attention to me up to that point, drifted down to my end of the bar and without any preamble, index, or glossary said: "Never drink anything that's still on fire." That's a natural law. It's as valid in Botswana and Bhutan as in Cody (unlike the old rain-follows-the-car-wash idea); it's obvious to just about everyone, but to my knowledge, it had remained unsaid for countless centuries; it's interesting; and it's important, in that it clearly isn't as trivial as peanut-buttered toast falling onto dust kitties.

The bartender walked away and said nothing more to me except, "Ketchup?" which I did not count as part of the universal law, even though his query was interesting, widespread, and important at the time. I believe I could have asked him if he was aware that he had just uttered a universal truth, and he would have ignored me—perhaps to the point of not even asking about the ketchup—and might even have thrown me out of his

tavern. That bartender was an unself-conscious messenger of a universal truth if ever there was one.

Another in my limited but pregnant collection of universal truths (a.k.a. natural laws, of course) came to me from the Nebraska State Poet, Bill Kloefkorn. Out of nowhere, he once told me, "When arranging a farmstead, it's really important to dig your hole and put the outhouse over it rather than locating the house first. You cannot imagine the trouble it takes to throw the dirt up through that little hole in the seat." Check it over. It fits all the criteria. (And I think it is significant that this, the least poetic of the universal laws I have encountered in my quarter-century search, came from a poet! I'm not ready to say for sure, but that may be part of the nature of natural laws, too.)

Another natural law in my collection came from my wife, giving me the opportunity to examine the process of discovery in depth. (Natural laws are like ghosts—the people who study them and want most to see them never do—so I have to experience everything about natural laws through someone else. That, too, may be a natural law.) Linda once announced, "The best two hours of a night's sleep start precisely an hour before your alarm goes off." It just came to her, Linda says, without fanfare or flashing lights, without choirs singing in Crosby, Stills, Nash, and Young harmonies. All at once, she says, there it was, in all its glory: a natural law.

And in all honesty, I'm comforted knowing we have a guy on the Supreme Court who understands that sort of thing. It's about time.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

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At dawn, a straggling leatherback returns to the ocean after laying her eggs on a Costa Rican beach. Nocturnal nesters, most females return to the water under cover of darkness.
Peter C. H. Pritchard

Bound for Deep Water

Leatherback turtles can pursue their prey half a mile straight down

by Scott A. Eckert

Of the deep-diving animals, the champions have always been assumed to be the marine mammals: the great whales and earless seals. Weddell seals, for instance, have been recorded diving to nearly 2,000 feet, elephant seals to nearly 4,000 feet, and sperm whales to more than 7,000 feet. Our recent investigations, however, suggest that a reptile may also be ranked among the ocean's greatest air-breathing divers. While measuring the dives of leatherback sea turtles near Saint Croix, in the U. S. Virgin Islands, my wife, Karen, and I recorded a 650-pound female that sounded to more than 3,330 feet and remained submerged for some thirty-seven minutes. Unfortunately, this unexpected behavior continued beyond the range of our recording instruments; we estimate that she reached a maximum depth of about 4,265 feet. While such behavior demonstrates that the leatherback is indeed a magnificent diver, it only hints at this living fossil's unique adaptations to life in the open ocean.

The leatherback is the only surviving member of the family Dermochelyidae; all other species of marine turtles belong to another group, the Cheloniidae. Genetics research conducted by Brian Bowen, of the University of Georgia, suggests that leatherbacks may be the most ancient species of living sea turtles. His preliminary mitochondrial DNA analysis, comparing leatherbacks with other sea turtles, indicates that leatherbacks diverged some time between 60 and 100 million years ago. Bowen's chronology is corroborated by evidence in the fossil record that the leatherback lineage emerged contemporaneously with the dinosaurs.

Not surprisingly, given the large size of many Mesozoic reptiles, the leatherback is, on average, the most massive reptile alive. While mature females typically exceed 660 pounds, the largest-known individual was an adult male that drowned after becoming entangled in a fishing net off Wales. It weighed 2,015 pounds and had a flipper span of eight feet. This unfortunate giant is the centerpiece of an exhibit on leatherback conservation at the National Museum of Wales.

A leatherback has an unusual life style

for a turtle, since it lives almost exclusively in pelagic, or open ocean, habitats. While other sea turtle species commonly graze in shallows near the shoreline, leatherbacks seldom approach land for any reason other than to nest. After entering the surf as small hatchlings, leatherbacks are seldom seen again by humans until they reach subadult size. Only a handful of juveniles have ever been encountered, and we know virtually nothing about the adult males. Females in the Atlantic reach sexual maturity when their top shell, or carapace, reaches a length of fifty-four to fifty-seven inches, while Pacific females are a bit smaller. Their age at maturity is unknown, but other, better-known sea turtles require some twenty to fifty years before they breed for the first time. When it is her time to reproduce (the time and place of mating remain a mystery), a female journeys to a nesting beach. Females arrive at these breeding grounds asynchronously over a four-month period.

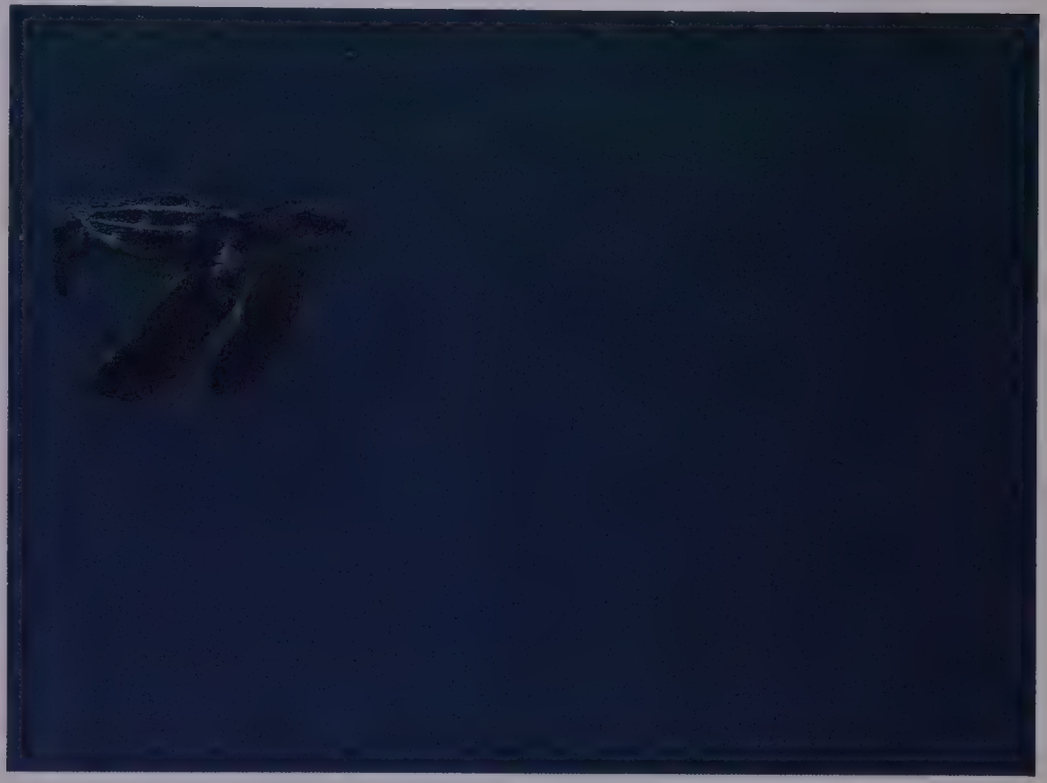
A gravid female approaches the chosen tropical beach—some believe it is her natal beach—and under the cloak of darkness leaves the shelter of the sea. Using her large hind flippers, she excavates a hole in the sand, then lays from seventy to ninety yolked eggs in the nest. Each cue-ball-sized egg is moist, soft, and leathery; it will not break when it falls into the deep cavity. Near the end of egg laying, a variable number of small, sometimes misshapen eggs, containing neither embryo nor yolk (just albumin), are deposited. Their purpose is not well understood, but they become desiccated over the course of incubation and may moderate humidity or air volume in the incubation chamber. (It is also possible that they have no function or are a vestige of some past mechanism not apparent to us today.)

When the full clutch has been laid, the turtle fills the nest cavity with sand, again using her hind flippers to pack it firmly. Next, she sweeps sand over the area, presumably to camouflage the nest's precise location. Finally, she returns to the sea. Ten days later, she will come back to this beach, dig another nest, and lay another clutch of eggs—a cycle that will be repeated as many as eleven times over the

Doug Perrine

Scrambling for the sea, these five-month-old turtles, left, were experimentally reared in captivity to protect them from predators and then released on a beach in Michoacán, Mexico. Hatchlings, like the one below, swim for the open ocean and are not seen again until they reach subadult size.

Scott A. Eckert



urse of the nesting season. The large mber of offspring helps insure that ne survive; each one measures only ee and a half inches from head to tail d must enter an ocean full of hungry edators. After she has laid her last tch of the season, the female will not urn to her nesting beach again for two three years.

While leatherbacks must nest on warm pical beaches, they do not generally e in tropical waters. Adults are usually nd in temperate or cold-temperate latides, as far north as Newfoundland and e Barents Sea, and also along the cold uthern coast of Chile. Indeed, leathercks are encountered throughout the rld's oceans, although nowhere in large numbers; their geographic range is the most extensive of any living reptile. Some of the longest migrations recorded for any animal have been made by this marine turtle. In 1970, a female leatherback was tagged while she nested in Suriname on the northeast coast of South America; less than one year later, she was captured off the coast of Ghana, West Africa, having traveled a minimum of 3,700 miles across the Atlantic Ocean. Similar, although shorter, postnesting migrations have been recorded for females dispersing from eastern Caribbean breeding grounds and traveling north along the Atlantic seaboard of the United States.

One reason the leatherback ranges so far may be its specialized diet. This giant of the sea feeds mainly on jellyfishes. Although a variety of jellyfishes and related prey are abundant, they are eaten by few other vertebrates. As one might suspect, a life spent eating mostly jellyfish requires some special adaptations to make the job easier. The leatherback has sharp cusps resembling a set of fangs on either side of its upper mandible and a single interlocking cusp on its lower jaw. Because of the species' relatively weak jaws, these cusps are essential in shearing chunks from larger prey, such as the lion's mane jellyfish, which may have a bell in excess of three feet in diameter.

Once the turtle has snapped up a jellyfish, the slippery prey is kept moving toward the stomach by long, flexible, downward-pointing spines that line the inner surface of the reptile's mouth and esophagus. How the turtle digests the jellyfish has been little studied, but the process is probably rapid, as a jellyfish consists largely of water. In most animals the stomach is an area for food storage and preliminary absorption, but in leatherbacks it is poorly defined. Food travels through the turtle's long, muscular esophagus and small stomach and into the small intestine, where most nutrient absorption occurs.

Leatherbacks are particularly well designed for long-distance travel. Broad shoulders and a wide anterior shell taper, teardrop fashion, to a blunt point at the rear, allowing nearly ideal hydrodynamic efficiency. Seven ridges along the length of the carapace improve laminar flow, much as a keel improves the efficiency of a boat moving through the water. The entire body, including the shell, is sheathed in the leathery but very smooth skin from which the animal derives its

Near Mexiquillo, Mexico, a female, below, lingers just beneath the surface before heading out to sea. Opposite, top: Electronic recorders reveal deeper dives during morning and shallower ones toward evening, as turtles follow the cyclic, daily migrations of jellyfish. Opposite, bottom: In the ocean near Sydney, Australia, a leatherback chomps on a jellyfish, its favorite prey.

Kim Clifton; Peter C. H. Pritchard

scientific name, *Dermochelys coriacea,* "the turtle covered in leathery skin."

Are there demonstrable advantages to the leatherback's proportions and streamlined shape? Jeanette Wyneken, of Florida Atlantic University, has shown that swimming leatherback hatchlings have a lower drag coefficient than hatchlings of other species, indicating more efficient propulsion. To swim the same distance as other sea turtles of comparable size and weight, leatherback hatchlings expend, on average, 20 percent less energy. Steering with their rear flippers, leatherbacks propel themselves forward (they seem incapable of going backward) during both the upstroke and the downstroke of the front flippers. The front flippers are more than half the length of the turtle's body and derive power from huge pectoral muscles, which can account for 30 percent of the animal's total body weight.

Leatherbacks are such consummate swimmers that they rarely stop moving, a behavior that has made it impossible to keep them in captivity. They adjust poorly to the confines of a tank and usually swim persistently against the walls until the tank breaks or they seriously harm themselves. Since leatherbacks cannot easily be studied in captivity, researchers have been developing methods of studying them at sea. We use the time-depth recorder, an instrument capable of recording dive depth, dive duration, ascent and descent rates, and surface times. Developed by Gerald Kooyman, of the Physiological Research Laboratory at the Scripps Institution of Oceanography, the device has been used to study diving marine mammals and penguins. My wife, Karen, and I have applied it to wild leatherbacks and have learned more about their behavior than could have been imagined a decade ago. In our initial trials of the device, we were so impressed by the deep dives of the gravid female off Saint Croix that we decided to undertake long-term studies of the timing and physiology of leatherback diving behavior.

During the 1984 and 1985 nesting seasons, with the assistance of Kooyman and Paul Ponganis, also of the Scripps Institution, we attached recorders to ten female leatherbacks that had just laid eggs. As a result, we were able to monitor their behavior when they returned to the sea. To our astonishment, we found that the turtles were diving almost continuously, day and night, averaging ten minutes per dive and five dives per hour. A typical dive was far from gradual; both descent and ascent were almost vertical. Upon returning to the surface, the turtles gulped a quick breath and immediately headed straight down again. Little or no time was given to sleep or rest. On closer examination, we noticed differences in the dives depending on the time of day. Night dives were shallower, with less variation in depth than day dives, although the overall time spent underwater at night was greater. The turtles spent relatively long periods at the surface during midday, perhaps basking to raise their body temperature.

Why the incessant diving? At first we were baffled, but we soon realized that the turtles were probably following their food source. In tropical waters, jellyfish are most common at great depths, in a biologi-

A Sea of Troubles: When a Prehistoric Giant Meets the Modern World

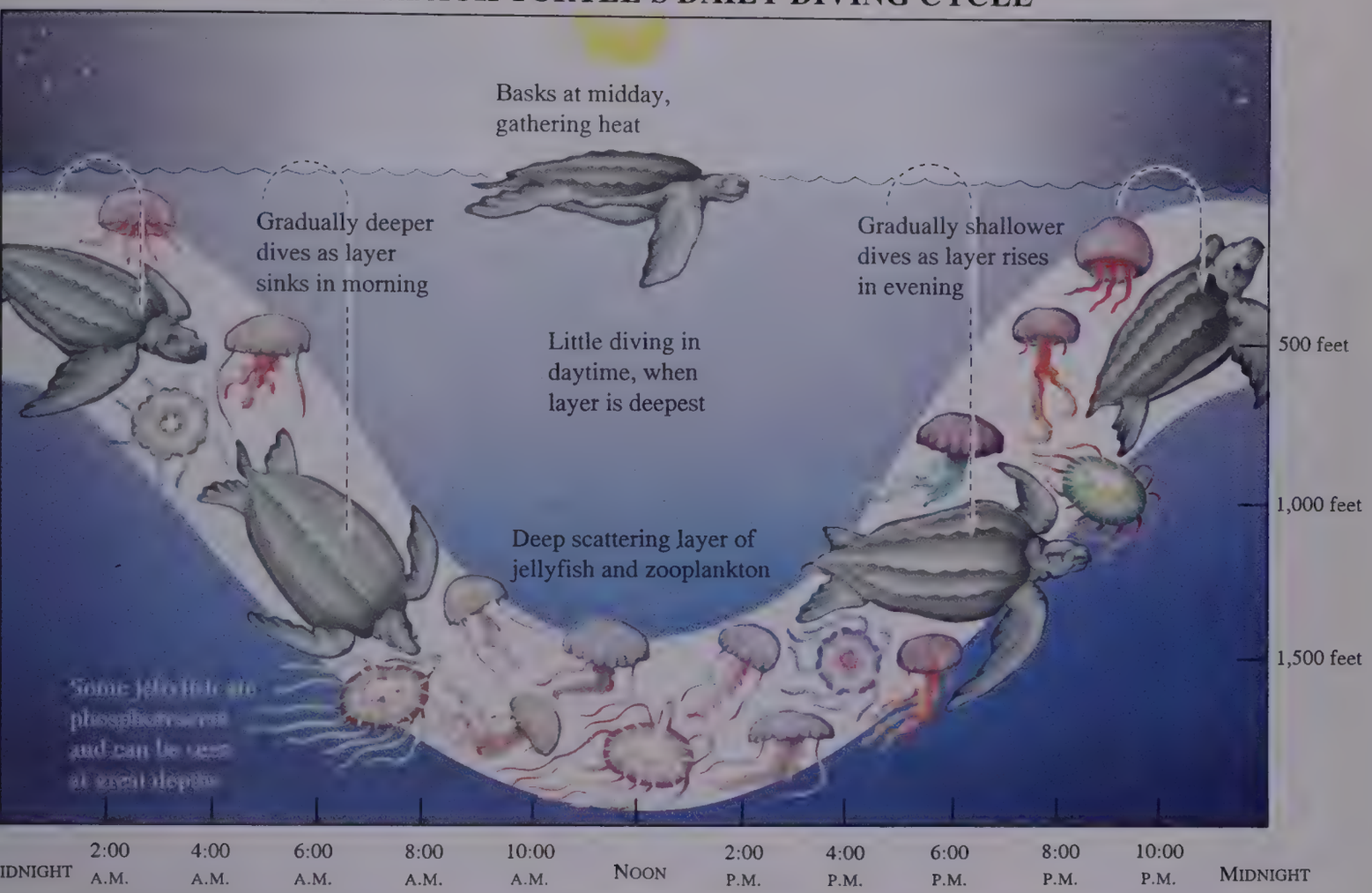
Although it has survived for nearly 100 million years, we may now be witnessing the twilight of the leatherback turtle's presence on our planet. Adult turtles are still being killed for their meat in some parts of the world, and many local populations have been reduced or extirpated.

In some countries, leatherbacks are decimated by unrelenting collection of their eggs, which are believed to be aphrodisiacs. On the beaches of Terengganu, Western Malaysia, for instance, the number of turtle nests plummeted from about 11,000 in 1956 to 280 in 1990.

Plastic bags discarded at sea pose another serious hazard; leatherbacks often mistake them for jellyfish, their favorite food. Autopsies of dead leatherbacks reveal that 40 to 50 percent of adult turtles had swallowed plastics. Such items can kill the turtles by blocking their digestive tracts. In addition, turtles must contend with miles of active and abandoned monofilament fishing nets that drift across the high seas. Once entangled, the animals starve or drown.

Commercial development, such as that planned for Mexico's Pacific coast, poses the latest threat. Still largely wild, this coastline supports nearly half of the breeding population of the world's leatherback sea turtles.—*S. A. E.*

LEATHERBACK TURTLE'S DAILY DIVING CYCLE

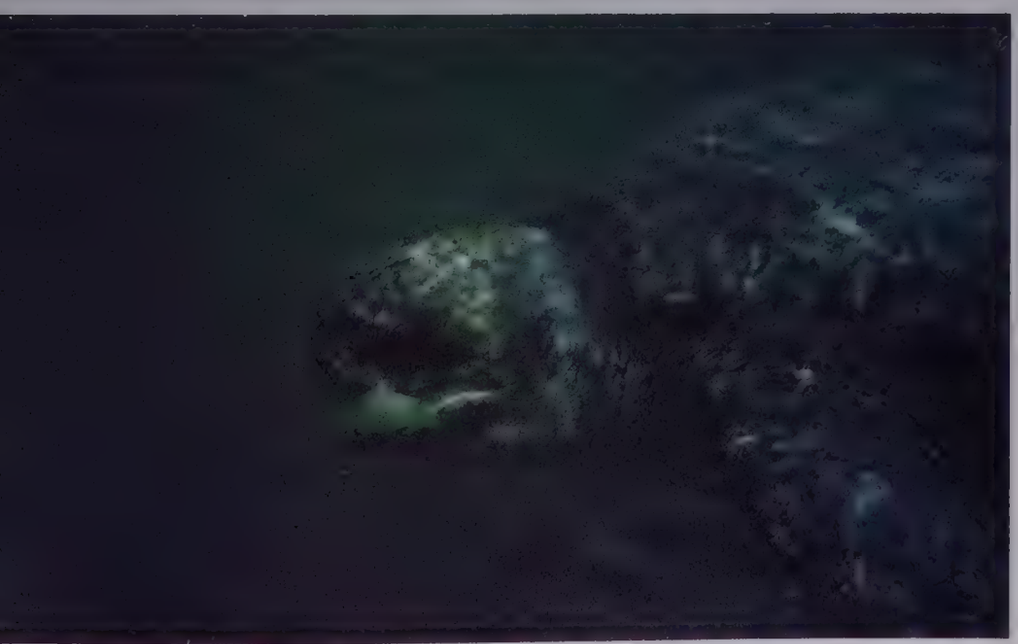


al zone called the deep scattering layer. Discovered shortly after the development f sonar, this zone consists of a horizontal ayer (or layers) of zooplankton that hov- rs below 1,800 feet during the day and nigrates to the surface at night. It is so ense with living creatures that early so- ar equipment interpreted it as a false cean bottom. Despite years of research, cientists cannot agree on why organisms ggregate in these deep, dense layers, hich represent a large portion of the zoo- lankton biomass in tropical oceans. How- ever, we do know that they migrate to the surface at night to feed on phytoplankton, then gradually retreat from the light of day, maintaining themselves within a gloomy zone that receives less than one percent of the surface illumination.

A leatherback's dives seem to follow the crepuscular movements of the deep scattering layer. As dusk approaches, the turtle executes shallower and shallower dives at more consistent depths than during the day. As dawn approaches, dives become increasingly deep, probably reflecting the pursuit of jellyfish as the invertebrates retreat from the light of dawn. We believe that the turtles feed in the upper layers of the water at night; during the day they either bask or resort to a more random dive pattern, because the aggregation of prey sinks beyond typical dive depths. Many species of jellyfish are luminescent, which enables the turtles to find them at night or even in deep water during the day.

These are inferences, of course, since we have not been able to directly observe leatherbacks feeding, but we have collected some additional circumstantial evidence. During the 1985 nesting season at Saint Croix, we weighed turtles each time they came ashore to nest. The results tend to corroborate the hypothesis that gravid females feed between bouts of nesting. Overall body-weight loss for most individuals was negligible, despite an average of 120 pounds of egg production. Indeed, two of the turtles gained weight as the season progressed.

In addition to learning when and why turtles dive we would very much like to know *how* they dive. Pressure at great depths can be extreme. For every 32.8 feet of descent, a turtle is subjected to an additional pressure of 14.7 pounds per square inch. At 3,280 feet, the turtle is pressed over each inch of its surface by 1,470 pounds of force; the impact is both physi-



n and Valerie Taylor; Ron Taylor Film Productions

Ron and Valerie Taylor; Ron Taylor Film Productions

An Australian diver swims alongside a leatherback, right, 100 miles north of Point Stevens. An adult's shell can be seven feet long. Below: A nesting female lays her eggs at Playa Grande, on the Nicoya Peninsula of Costa Rica, where local people have joined the effort to protect leatherbacks from egg poachers.

Peter C. H. Pritchard

cal and physiological. Pressure acts on air trapped in the body, the lungs, the trachea, and even within vascular tissue. Tissue around these gas pockets can deform and rupture.

Under great pressure, the nervous system, including the brain, can become "oversensitized"—a phenomenon known as high-pressure nervous syndrome, which can result in convulsions and even death. Also, there is the more familiar decompression sickness, commonly known as the bends, caused by nitrogen bubbles forming in the blood during steep, rapid ascents from deep dives.

How do the deep-diving vertebrates—whales, seals, penguins, and leatherback turtles—avoid decompression sickness and other hazards when they dive to great depths, stay down for long periods of time, and ascend quickly? First, only small amounts of nitrogen are available to the tissues. Many of the deepest-diving marine mammals have small lungs and forcefully exhale prior to diving. In addition to reducing buoyancy so that they can dive more easily, this severely limits the amount of nitrogen (a major component of air) available to the bloodstream.

We don't know if leatherbacks exhale prior to diving, but they do have relatively small lungs for their body size. Small lungs, however, also mean reduced carrying capacity for oxygen. Some deep-diving mammals have compensated for this lack by evolving an increased blood volume, a greater density of red blood cells to carry the oxygen, and elevated concentrations of an oxygen-storing pigment (myoglobin) in the muscles. The leatherback is the only reptile to employ this same overall strategy. The concentration of myoglobin is almost three times higher in leatherbacks than in any other reptile, and they have very dense concentrations of red blood cells in the bloodstream.

High pressure also poses a challenge to the deep diver in terms of potentially crushing forces that could compress the chest cavity, causing broken bones or tissue damage. Having small lungs reduces the risk of damage by external squeezing. Furthermore, the leatherback's frame is extremely flexible. The entire skeleton exhibits a high cartilage-to-bone ratio, which allows any internal air stores to be compressed without damaging tissues or breaking bones. Unlike its hard-shelled relatives, with their armorlike shields of fused ribs, the leatherback has a shell made up of widely separated ribs embedded in a thick, oily, cartilaginous tissue. A matrix of thin, bony plates, three-fourths of an inch in diameter, gives the tissue shape, and the whole structure is overlaid with leathery skin. The plastron (belly) has almost no bone, only a flexible cartilaginous ring of tissue for structural support. Even the long bones in the flippers are very pliant.

The extensive geographic range over which the leatherback roams also poses special physiological challenges for a reptile. The turtle must be able to tolerate enormous fluctuations in environmental temperature. During the four-month nesting season, it lives in waters that may be as warm as 86° F. However, during the intervening twenty months or more, the turtle is likely to reside in waters that may be 41° F or even less. Typically, reptiles and fishes have body temperatures roughly

equivalent to that of their surroundings. In a cool environment, metabolic enzyme efficiency is greatly reduced and the animals cannot remain active. Some scientists hypothesize that climatic cooling was partly responsible for the extinction of some former contemporaries of the leatherbacks, such as the dinosaurs. But adult leatherbacks have been observed swimming around icebergs!

Research by zoologists Wayne Friar, Robert Ackerman, and Nicholas Mrosovsky has shown that the leatherback can maintain a body temperature of 64° F in 41° F water. Several adaptations conserve heat generated by muscular activity or gained during basking. A heavy layer of fat, oil, and cartilage acts as insulation, much as the blubber in marine mammals does. And like some marine mammals, the leatherback has bundles of vascular tissue in its front flippers. Each outgoing artery is paired with an incoming vein, an arrangement that acts as a countercurrent heat exchanger. This unusual mechanism prewarms the blood flowing in from the extremities, preventing the venous blood from cooling the internal organs and muscles. At the same time, it cools the outgoing blood, precluding the loss of core heat to the extremities.

Shape and color may also be advantageous for keeping warm. The leatherback's nearly cylindrical body minimizes the surface area exposed to cooling water. If the turtles do indeed bask at midday, then the overall black color is likely to be advantageous for heat absorption. Finally, preliminary evidence indicates that leatherbacks may have a layer of a special thermogenetic tissue called brown fat, a substance known to generate heat metabolically in some other species.

All these recent discoveries about the leatherback's physiology and behavior show it to be an oceanic specialist whose adaptations are finely tuned to a life of deep diving in the open ocean. Studying them, I have become much less "mammalocentric"; many features that I had previously assumed to be the exclusive invention of marine mammals may have actually evolved long before, in grandfather turtle. □

A Kayapo Indian in Brazil's Xingu Reserve fishes with traditional bow and arrow.
Thomas L. Kelly

Civilization and Its Discontents

Amazonian Indians experience the thin wedge of materialism

by Katharine Milton

For more than a decade now, I have led a double life. I spend part of my time in the United States, living in an apartment in Berkeley and teaching anthropology classes at the University of California. The rest of my time is spent in the Amazon Basin, where I live in the company of recently contacted Indian groups, studying their traditional ecology and features of their tropical forest environment. On returning to the United States after one of these extended stays in the jungle, I always experience culture shock as I strive to regain control of my possessions, which I have totally forgotten about.

Usually my first act is to retrieve my dust-covered car, which has languished for some six to eighteen months in a garage. The battery must be charged, and then I must wash and vacuum the car, fill it with gas, and check out its many parts. Once I am mobile, I rush to a large supermarket to stock up on cleaning supplies and food. My first few days are completely taken up with chores; there never seems to be a moment when I am not contemplating some type of home repair or new purchase.

And then there is my body. What a job it is to live up to what is expected of the average American. I must visit the dentist—often more than one kind of dentist—to be sure my teeth are performing at top level. The doctor must be seen for a checkup; my eyes must be examined, glasses and contact lenses adjusted, and so on. I begin to wonder how my friends in Berkeley manage to have any free time at all, since I have fewer possessions than they do—I own no television set, no stereo or compact disk player, no video machine, home computer, food chopper, or any number of other items my friends seem to dote on. I don't even own my apartment.

Plunged back into life in Berkeley, I see myself as a slave of material possessions, and I notice that I deeply resent the time and energy required to maintain them. Nothing could be more different from the life I have been leading with hunter-gatherers deep in the rain forests of Brazil, where people have almost no possessions, and those that they do have are made from local forest materials and are entirely biodegradable.

The groups I have visited live far from any cities, towns, or commercial enterprises. They include the Mayoruna and Maku from Amazonas State; the Arara, Parakana, and Arawete from Pará State; and the Guaja from Maranhão State—peoples so remote and little known that few outside their immediate geographic area have heard of them. Often I am one of the first nonindigenous females many members of the group have ever seen. With my pale skin and hair I am a truly terrifying apparition to younger children, who sometimes scream with fear when they first see me.

All these peoples have been recently contacted: only a few months or, at most, years have passed since the Brazilian Indian Bureau (FUNAI) managed to establish a formal relationship with them. Previously, these groups avoided or were strongly hostile to outsiders, but with contact, they have permitted a few Indian Bureau employees to live with them, to assist them, and at times, protect them in dealings with other Indian groups or members of the wider Brazilian society. Living with these people has given me the chance to see how even modest changes in their

traditional lifeways—the introduction of something as innocent in appearance as a metal cooking pot or ax, a box of matches or some salt—can be the thin edge of a wedge that will gradually alter the behavior and ecological practices of an entire society.

These people typically live in small villages of fewer than a hundred inhabitants, in some cases in groups of only fifteen or twenty. Most practice slash-and-burn agriculture on a small scale, complementing crop foods with wild game and fish, forest fruits and nuts, and occasionally, wild honey. For some months life may revolve around the village, but sooner or later every group I have worked with leaves, generally in small parties, and spends weeks or even months traveling through the forest and living on forest products.

Throughout the forest there are paths that the Indians know and have used for generations. They travel mainly when wild forest fruits and nuts are most abundant and game animals are fat, but families or small groups may go on expeditions at other times of year as well. They trek a few miles, make a temporary camp, and then hunt, gather, and eat several meals in the area before moving on to a new site. At certain times of year, many groups relocate to the borders of large rivers, where they obtain turtle eggs or other seasonal river foods.

The accumulation of possessions would be an impediment to this seminomadic life style. Whenever individuals go on a trek, they carry everything they need. Leaving possessions behind in a thatch-and-pole hut, to be retrieved later, is not an option, since the humid climate and voracious insects would quickly destroy them. Great numbers of insects often live inside Indian dwellings, principally jungle cockroaches that hide in the roof thatch by day but come out by the thousands at night. Indians seem oblivious to them, letting them run about on their bodies and even crawl on the food so long as they are not perched on the next bite.

Granted, these are generally soft-bodied, small jungle cockroaches and not the tough, large roaches of our urban areas, but even so, I found it difficult to adjust to them. My frantic efforts to remove cockroaches from my body and clothes were regarded as strange by my Indian hosts. At one site, I resorted to storing my clothing each night in a heavy plastic bag, which I sealed shut and suspended from a piece of plastic fish line tied to a roof pole. Otherwise, at night, the roaches covered my shirt and pants so thoroughly that often the fabric could not be seen. Although the roaches would be gone the next morning, they would leave a musty smell; further, just the idea of wearing garments that I had seen coated with cockroaches gave me a squirmy, unclean feeling.

On the forest treks, the women are invariably the most burdened, something Western observers often find difficult to understand or accept. A woman will walk for hours carrying a toddler, a large palm basket containing fifty or more pounds of animal or plant foods, hammocks, a cooking utensil or two, a machete, and the family pets, such as parrots, monkeys, and young puppies. In all the groups I have observed, the women's legs and feet are deformed by the pigeon-toed walk they adopt to give them added traction and stability on the slippery, narrow forest trails. The feet of adult men turn in only slightly, because men usually carry nothing heavier than a bow and arrows (osten-

A Urueu-Wau-Wau man, left, can prepare all his hunting equipment from renewable forest resources. Below: A woman from the same group bears a heavy load, a common female obligation in the Amazonian forest. The aluminum pot indicates the introduction, for good or ill, of manufactured products.

Photographs by Loren McIntyre

sibly to be free to take advantage of any hunting opportunities).

The most important possession the Indians carry with them, however, is knowledge. There is nothing coded in the genome of an Indian concerning how to make a living in a tropical forest—each individual must become a walking bank of information on the forest landscape, its plants and animals, and their habits and uses. This information must be taught anew to the members of each generation, without the benefit of books, manuals, or educational television. Indians have no stores in which to purchase the things they need for survival. Instead, each individual must learn to collect, manufacture, or produce all the things required for his or her entire lifetime.

Because people differ in their talents, the pool of community information and abilities is far greater than its component parts. Individual men and women have their own areas of expertise, as well as their share of general knowledge. Members of the group know whom to consult for special information on hunting practices, the habits of particular game animals, rituals, tool manufacture, crop varieties, and the like.

Tropical-forest Indians talk incessantly, a characteristic I believe reflects the importance of oral transmission of culture. When I lived with the Maku, I slept in a hammock inside a small communal palm shelter. If a Maku awoke in the middle of the night, he usually began to talk or sing in a very loud voice—apparently without any thought that anyone might object to this behavior. It was considered normal, what you do when you wake up in the middle of the night and aren't sleepy. Others learn, as I did, to sleep through it or, if they aren't sleepy, to listen to it. Vocal expression apparently is expected and tolerated in Maku culture, no matter what the hour, an indication to me of how much it is valued.

Unlike our economic system, in which each person typically tries to secure and control as large a share of the available resources as possible, the hunter-gatherer economic system rests on a set of highly formalized expectations regarding cooperation and sharing. This does not mean hunter-gatherers do not compete with one another for prestige, sexual partners, and the like. But individuals do not amass a surplus. For instance, no hunter fortunate enough to kill a large game animal assumes that all this food is his or belongs only to his immediate family.

Quite the reverse is true: among some forest peoples, the hunter cannot eat game he has killed or is restricted to eating only one specific portion of his kill. Game is cut up and distributed according to defined patterns particular to each group and based in large part on kinship and marriage obligations. A hunter may have amazing luck one day, moderate luck on another, and no luck at all on a third. But he can usually expect to eat meat every day because someone bound to him in this

Txukahamei Indians, right, sharpen an ax used to clear a field near the Xingu River. Below: His machete at his side, a Urueu-Wau-Wau roasts wild boar. The efficacy of steel tools is instantly appreciated, but their price may be the loss of traditional skills, patterns of social cooperation, and ultimately independence.

Photographs by Loren McIntyre

system of reciprocity may well make a kill and share the meat.

Despite the way their culture traditionally eschews possessions, forest-living peoples embrace manufactured goods with amazing enthusiasm. They seem to appreciate instantly the efficacy of a steel machete, ax, or cooking pot. It is love at first sight, and the desire to possess such objects is absolute. There are accounts of Indian groups or individuals who have turned their backs on manufactured trade goods, but such people are the exception.

When Cândido Rondon, the founder of the Indian Protection Service in Brazil, began his pacification efforts in the early 1900s, he used trade goods as bait to attract uncontacted Indians. Pots, machetes, axes, and steel knives were hung from trees or laid along trails that Indians frequented. This practice proved so successful that it is still employed (*see* "Overtures to the Nambiquara," by David Price, *Natural History,* October 1984).

Whether they have been formally contacted or not, forest-living groups in the Amazon Basin are probably well aware of steel tools and metal cooking pots. After all, such goods have been in circulation along trade routes in these regions for centuries, and an Indian does not have to have seen a non-Indian in order to acquire them. However, such manufactured goods are likely to be extremely scarce among uncontacted groups. When the Arara Indians were first approached in 1975, they fled their village to escape the pacification party. Examination of their hastily abandoned dwellings showed that stone tools were still being used, but a few steel fragments were also found.

Since they already appreciate the potential utility of manufactured goods, uncontacted Indians are strongly drawn to the new and abundant items offered to lure them from isolation. Once a group has been drawn into the pacification area, all its members are presented with various trade goods—standard gifts include metal cooking pots, salt, matches, machetes, knives, axes, cloth hammocks, T-shirts, and shorts. Not all members of the group get all of these items, but most get at least two or three of them, and in a family, the cumulative mass of new goods can be considerable.

The Indians initially are overwhelmed with delight—this is the honeymoon period when suddenly, from a position in which one or two old metal implements were shared by the entire group, a new situation prevails in which almost every adult individual has some of these wonderful new items. The honeymoon is short-lived, however. Once the Indians have grown accustomed to these new items, the next step is to teach them that these gifts will not be repeated. The Indians are now told that they must work to earn money or must manufacture goods for trade so that they can purchase new items.

Unable to contemplate returning to life without steel axes, the Indians begin to produce extra arrows or blowguns or hunt additional game or weave baskets beyond what they normally need so that this new surplus can be traded. Time that might, in the past, have been used for other tasks—subsistence activities, ceremonial events, or whatever—is now devoted to production of barter goods. In addition, actual settlement patterns may be altered so that the indigenous group is in closer, more immediate contact with sources of manufactured items. Neither of these things, in itself, is necessarily good or bad, but each does alter traditional behavior.

Thus, the newly contacted forest people are rapidly drawn into the wider economic sphere (even into the international economy: for example, the preferred glass beads for personal adornment come from Czechoslovakia). The intrusion of every item—mirrors, cloth, scissors, rice, machetes, axes, pots, bowls, needles, blankets, even bicycles and radios—not only adds to the pressure on individuals to produce trade goods but also disrupts some facet of traditional production.

Anthropologist Paul Henley, who worked with the Panare, a forest-based people in Venezuela, points out that with the introduction of steel tools, particularly axes, indigenous groups suffer a breakdown in the web of cooperative interdependence. In the past, when stone axes were used, various individuals came together and worked communally to fell

trees for a new garden. With the introduction of the steel ax, however, one man can clear a garden by himself. As Henley notes, collaboration is no longer mandatory nor particularly frequent.

Indians often begin to cultivate new crops, such as coffee, that they feel can be traded or sold easily. Another is rice, which the Indian Bureau encourages forest peoples to plant because, of course, all "real" Brazilians eat rice every day. Rice is an introduced crop both to Brazil and to forest Indians. Traditional crop foods, the successful cultivation of which has been worked out over generations in the forest environment and which are well suited to the soil conditions in particular regions, may become scarce, with the result that the Indian diet becomes unbalanced.

Indians who traditionally plant manioc as a staple crop may be encouraged to increase the size of their fields and plant more manioc, which can then be transformed into *farinha,* a type of cereal that can be sold in the markets. Larger fields mean more intensive agricultural work and less time to hunt—which also affects the diet. The purchase of a shotgun may temporarily improve hunting returns, but it also tends to eliminate game in the area. In addition, shotgun shells are very expensive in Brazil, costing more than $1 U.S. apiece. Dependence on the shotgun undermines a hunter's skill with traditional hunting weapons, such as blowguns and bows and arrows, as well as the ability required to manufacture them.

Clearing larger areas for fields can also lead to increased risk from diseases such as malaria and leishmanaisis, because cleared areas with standing water of low acidity permit proliferation of disease-bearing mosquitoes and flies. New diseases also appear. Anthropologist-epidemiologist Carlos Coimbra, Jr., for example, has shown that Chagas disease, which is transmitted to humans by trypanosome-carrying assassin bugs, apparently does not yet affect Indian populations in lowland areas of the Amazon Basin. Only when Indians cease their seminomadic way of life and begin to live for prolonged periods in the same dwellings can Chagas-carrying bugs adjust their feeding behavior and begin to depend on human hosts rather than small rodents for their blood meals.

The moment manufactured foods begin to intrude on the indigenous diet, health takes a downward turn. The liberal use of table salt (sodium chloride), one of the first things that Indians are given, is probably no more healthful for them than it is for Westerners. Most Indians do not have table salt; they manufacture small quantities of potassium salts by burning certain types of leaves and collecting the ash. Anthropologist Darrell Posey reports that the Kayapo Indians of Brazil make salt ash from various palm species and use each type for specific foods.

Sweets and other foods containing refined sugar (sucrose) are also given to Indians, whose wild fruits, according to research by botanists Irene and Herbert Baker, contain primarily other sugars, such as fructose. Indians find that foods containing sucrose taste exceptionally sweet, and they tend to crave them once sampled. While a strong, sugary taste in the natural environment might signal a rare, rich energy source, the indiscriminate consumption of canned foods, candies, and gums containing large amounts of refined sugar contributes to tooth decay and can lead to obesity and even health problems such as diabetes.

Results of dietary change are often difficult to anticipate. Anthropologist Dennis Werner found that the Mekranoti of central Brazil, who did not make pottery, traditionally roasted most of their food. But the introduction of metal cooking pots allowed them to switch to boiled foods. This, in turn, allowed nursing mothers to provide supplemental foods to their infants at an earlier age. Werner found that the average nursing period in the Mekranoti had dropped steadily from 19.7 months prior to 1955 to 16 months in recent years, which corresponded to the period of steady increase in the use of metal cooking pots in the village.

One of the first things the Indian Bureau doctors generally do after contact is try to protect the Indians from the Western diseases that may be communicated to them during their first prolonged interac-

Loren McIntyre

Relaxing in store-bought hammocks, Urueu-Wau-Wau Indians, right, enjoy an assortment of manufactured goods. An Arawete woman's cloth, below, was woven from cotton she grew and dyed herself, but her baby's hat testifies to outside contact.

Katharine Milton

tion with outsiders. The doctors give them immunizations and may also hand out drugs to prevent or eradicate dangerous malarias. Pregnant women, infants, and preadolescents often receive massive doses of antibiotics. Antibiotics and antimalarial drugs, although helpful in some respects, may also have detrimental effects. For example, individuals exposed to antibiotics in utero or when young generally have teeth that are abnormally dark and discolored. Some drugs are reputed to interfere with fertility among women in recently contacted groups. If this lack of fertility combines with a drop in population size due to deaths from new diseases, a population can fall to a precarious low.

Perhaps the most critical disruption suffered by these groups, however, concerns how detailed information on features of the forest environment is diluted and forgotten. This is the pool of shared knowledge that traditionally has been the bedrock, the economic currency, the patrimony of each of these nontechnological forest societies. Manuel Lizarralde, a doctoral student at the University of California, Berkeley, who has done ethnobotanical work with the Bari of Venezuela, reports that in just a single generation there was a staggering loss of information about the identity of forest trees and their uses.

Despite this tale of disruption, disease, and destruction, many of the indigenous forest cultures are proving to be far more resilient than might be expected. The indigenous peoples remaining today in the Amazon Basin are true survivors who have successfully resisted the diseases, explorers, missionaries, soldiers, slave traders, rubber tappers, loggers, gold miners, fur traders, and colonists who have persistently encroached on them during the past five centuries.

Anthropologist Bill Balée, for example, has found that the Ka'apor Indians of Maranhão State, in peaceful contact with outsiders since 1928, still maintain many features of their traditional economy, social organization, and ritual life. He attributes this to the continued integrity of the nuclear family and the persistence of specific ritual duties between husband and wife that prohibit certain foods at different seasons or life stages. Such ritual practices have not only spared red-legged tortoises and other wild resources from being overharvested but have also diffused hunting pressures over a large area, thereby contributing to the persistence of the traditional economy.

Unfortunately, cultural persistence will do indigenous peoples no good if their tropical forest habitat is destroyed. Deforestation is primarily the result of outside influences, such as lumbering, cattle ranching, and colonization, that are permitted by government policies. Some estimates suggest that all remaining tropical forests will be destroyed by the year 2045.

Once the technological roller coaster gets moving, it's hard to jump off or even pause to consider the situation. Some say, so what? We can't all go back to the jungle, we can't all become forest-living Indians. No, we can't. But as I stand in my apartment in Berkeley, listening to my telephone's insistent ring and contemplating my unanswered mail, dusty curtains, dripping faucets, and stacks of newspapers for recycling, I'm not sure we wouldn't be far happier if we could. □

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A prized edible, the widespread oyster mushroom is a fleshy gill fungus found in overlapping clusters on trees and logs. It feeds on wood, but its filaments, or hyphae, also paralyze and digest nematode worms.

David Cavagnaro

Jekyll-Hyde Mushrooms

Whether dining on dead wood or living creatures, these fungi are crucial to a forest's survival

by George Barron

Walking along woodland trails in the fall of the year is fun for someone like me who works with fungi. All kinds of attractive mushrooms spring up from the cool, moist forest floor. Bracket fungi or fleshy gill fungi can cover rotting logs. Often, there are exciting finds such as earthstars, bird's nest fungi, or stinkhorns.

The colorful forms we call mushrooms are the fruit bodies of fungi. Prod a puffball with a stick and a brown cloud of tiny spores emerges, which may be scattered by capricious winds. The common meadow mushroom releases a hundred million spores an hour for days on end. A giant puffball contains about a trillion spores! Where do mushrooms get the energy for all this productivity?

Each fruit body is sustained by miles of microscopic filaments, called hyphae, that permeate the hidden world within the rotting log or forest debris. A bundle of a thousand of them is no thicker than a human hair. Enzymes secreted by the hyphae break down complex carbohydrates into nutritive sugars, which are transported to the mushroom.

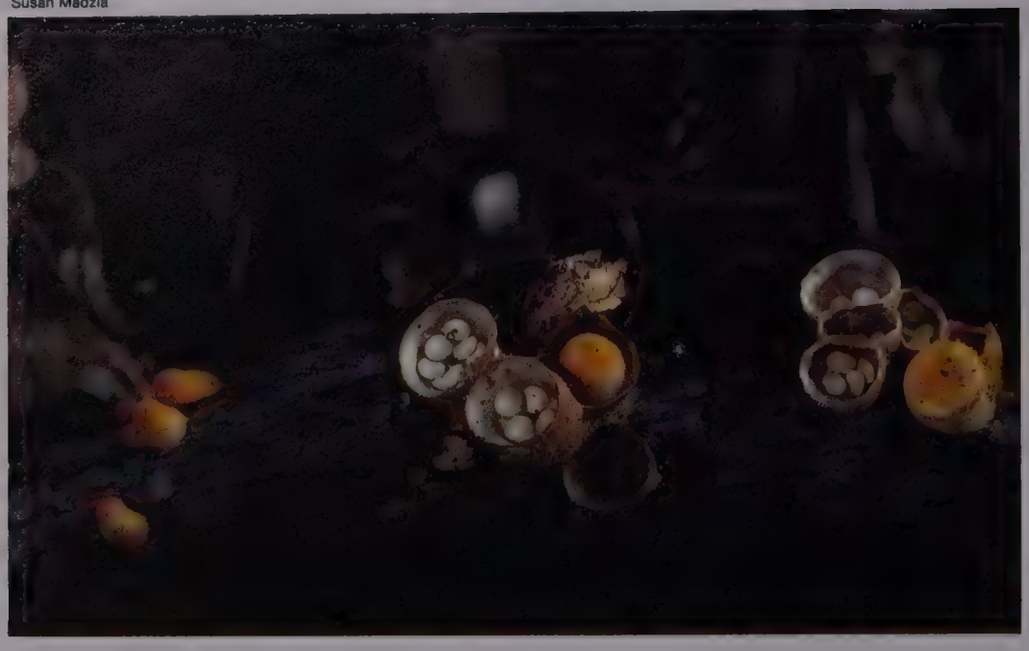
In woodland soils, fungi play two major roles. One group, saprophytic mushrooms, degrades woody materials; these fungi are the garbage disposal units of the forests. Without them the planet would be littered with dead trees, and forests would suffocate in their own debris. Each year microbial degradation of plant debris returns 85 billion tons of carbon to the atmosphere in the form of carbon dioxide; the bulk of this job is performed by fungi.

A second group, the mycorrhizae, grows beneath the soil and is as important to the forest ecosystem as are the wood-eating mushrooms. Forming sheaths around tree roots, mycorrhizae assist them in absorbing water and minerals essential to growth. They can do the job much more efficiently than the tree's own root hairs. In return, the tree feeds the fungi with sugars synthesized in its leaves. All conifers, and even such deciduous species as beech and birch, cannot survive without mycorrhizal fungi. Because of these crucial relationships, fungi are the dominant microscopic life forms in field and woodland soils; their living proto-

Masana Izawa; Nature Production

Bird's nest fungus "eggs," below, contain the spores; when raindrops splash inside the cup, these spore cases are catapulted out of the "nest." Right: Tough, leathery, and colorful, turkey tail bracket fungi overlap to cover logs. Like bird's nest fungi, they feed on dead wood and are also active hunters of bacteria.

Susan Madzia



plasm outweighs all other groups combined. Each acre contains about 2,500 pounds of fungi—about equal to the weight of twenty-five sheep.

Scientists used to think of wood-decaying fungi as benign saprophytes concerned only with the dull routine of carbon recycling. Not quite so, it has turned out. During the past decade or so of studying fungi in the Environmental Biology Laboratory at Ontario's University of Guelph, we discovered a more sinister aspect to the story. Many of these innocuous-looking fungi spend much of their lives as predators, attacking and consuming a host of microscopic life forms. We now know that hundreds of species employ a remarkable arsenal of weapons that allow them to lure, trap, lasso, paralyze, colonize, or enzymatically dissolve multitudes of live victims.

Among the organisms attacked and consumed are nematodes, rotifers, amoebas, copepods, and bacteria. Some fungi even feed upon their own kind. Nematodes, sometimes called roundworms or eelworms, are a source of food for more than 150 species of fungi. Tiny nonsegmented worms, usually less than a millimeter long, they are a very successful group, found by the millions in every square yard of forest and meadow. Sightless, they respond to chemical signals to find food and detect danger. Feeding on bacteria, spores, or other organic specks, they pump food down their gut by a muscular esophagus.

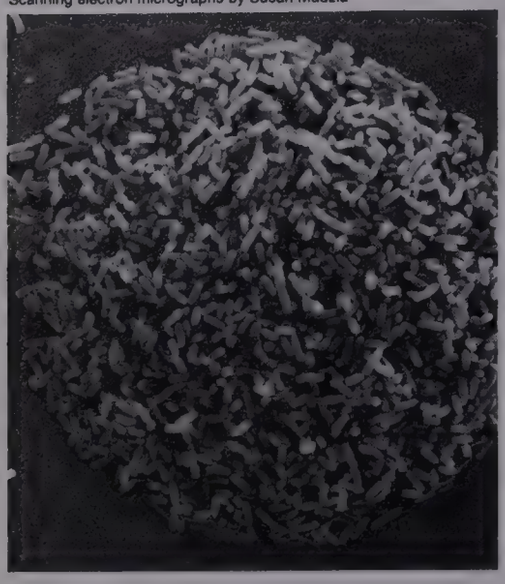
To capture nematodes, fungi send out extensive systems of filaments throughout the soil or rotting logs. The net fungus, *Arthrobotrys oligospora,* increases its odds of trapping prey by sprouting net traps coated with adhesive at intervals along its hyphal threads. Standing up from the surface like croquet hoops, the traps release a chemical attractant that nematodes find irresistible. When they respond to this chemical siren song, they are lured to their death.

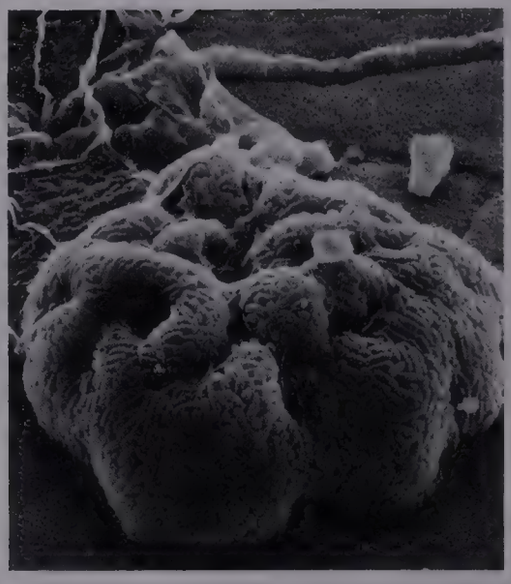
Nematodes are powerful, muscular little animals; when first caught, they thrash vigorously in their attempts to struggle free. The fungal adhesive, however, is the biological equivalent of Krazy glue, and the nematodes cannot escape. Swedish researchers, led by Birgit Nordbring-Hertz, discovered a protein on the surface of the net trap that recognizes specific sugar molecules in the nematode's cuticle. On contact, a chemical bond, which cannot be broken by physical force, forms between the net and the worm. The "glue" is just as effective underwater. Thus, contact with a net, even for a few seconds, holds the worm fast. Strands of hyphae invade its body, releasing paralyzing toxins; then, the invasive fungi digest the worm from inside its corpse.

Even more sophisticated than the sticky

In a healthy colony of bacteria (magnified 1,250 times), below, left, cells are whole and well separated. Below, right: Attacked by hyphae of a gill fungus, the colony is killed and digested by enzymes. Right: Another bacteria eater is the tiny, brilliant orange Mycena leaiana, *commonly clustered on hardwood logs in North American woodlands.*

Scanning electron micrographs by Susan Madzia





net is the constricting ring, produced by *Arthrobotrys anchonia* and other hunters of nematodes. In this case, hyphal branches circle back upon themselves to form three-celled rings baited with a chemical attractant. Responding to the lure, a nematode may blunder into a ring. When its cuticle touches the ring's inner walls, there is an explosion of activity. Expanding inward with dramatic speed, ring cells blow up to three times their volume in a tenth of a second, crushing the nematode's body.

Other tiny animals are also captured by fungi, using many different methods. In ponds and ditches, the fungus *Zoophagus* produces what Howard Whisler, of the University of Washington, called lethal lollipops. The slightly swollen ends of short lateral branches are extremely attractive to microscopic animals called rotifers, which try to swallow the "lollipops" and become stuck by their mouths. Once engulfed, the tip sprouts hyphae that invade and colonize the hapless victim.

Surrounded by incalculable tons of wood for energy, why have these fungi evolved the capabilities of active predators? In this modern age we are assailed from all sides with advice on good nutritional practices. Don't eat this! Be sure to include that! The bottom line, however, is that a balanced diet should include both carbohydrate and protein. Simple lower life forms also need to have a reasonable balance between the carbon (C) in carbohydrates and the nitrogen (N) in protein. A good ratio is about thirty parts of C to one part of N.

Wood is very high in carbon (cellulose and lignified cellulose) and very low in nitrogen (protein content), resulting in a C/N ratio of up to 500:1. Wood is so low in nitrogen that it is very difficult for most organisms to use it for food.

Organisms using wood or cellulose have to find a way of dealing with this nutritional imbalance. The solution adopted by many wood-decaying fungi is remarkable. Like the insect-devouring pitcher plants or Venus' flytraps that live in nitrogen-poor bogs, they have evolved ingenious mechanisms for capturing small creatures as nitrogen sources. Thus, the wood-decaying Jekyll becomes the carnivorous Hyde.

In the nitrogen-deficient environment colonized by cellulolytic fungi, any species that finds an easy way to get protein has a competitive edge. And large populations of microorganisms have always shared the fungal environment of rotting logs and organic detritus. These facts have led us to believe that predatory fungi were originally cellulose degraders that, over evolutionary time, "learned" the trick of capturing little animals to solve their nutritional needs. In laboratory studies in England, mycobiologist Rod Cooke and his colleagues studied predatory fungi and found that most do retain the ability to break down cellulose.

Apparently, there are a large number of fungi with Jekyll-Hyde personalities that can shift between herbivory and carnivory as the need arises. At present, we do not know whether most fungi are strictly saprophytic or carnivorous, or how many species can switch back and forth. Among the mushrooms we have investigated is the familiar oyster mushroom (*Pleurotus ostreatus*), highly prized as an edible fungus, and the wood blewit (*Lepista nuda*), which grows on organic debris on the forest floor. Cultivated in petri dishes, the oyster mushroom produces tiny secretory cells, each bearing a droplet of fluid. Upon being touched by a nematode, the cells splash fluid over the worm's head. Reacting as if it had touched a hot stove, the worm immediately retreats. But the potent toxin causes major structural damage, and the nematode is soon immobilized. As the victim lies paralyzed, the

fungus senses its location and homes in on its body orifices. Hyphal threads grow through the mouth of the victim and into its body to digest its still-living tissues. Shades of a Saturday night horror film!

Another group of fungal hunters we studied have filaments with bumps, called clamps, along their length that told us that they are related to mushrooms. No one had ever seen them produce a fruit body, however, and we were studying the manner in which these fungi capture nematodes using their hourglass-shaped adhesive cells. After several weeks, we were delighted to find a tiny mushroom fruit body growing in a petri dish among the luxuriant filaments. We identified it as a *Hohenbuehelia,* well known as a saprophyte on decaying wood and debris. My graduate student Greg Thorn then tested all the available species of *Hohenbuehelia,* and related fungi, and found a whole cluster of mushrooms, previously thought to be passive saprophytes, that were in fact aggressive carnivores.

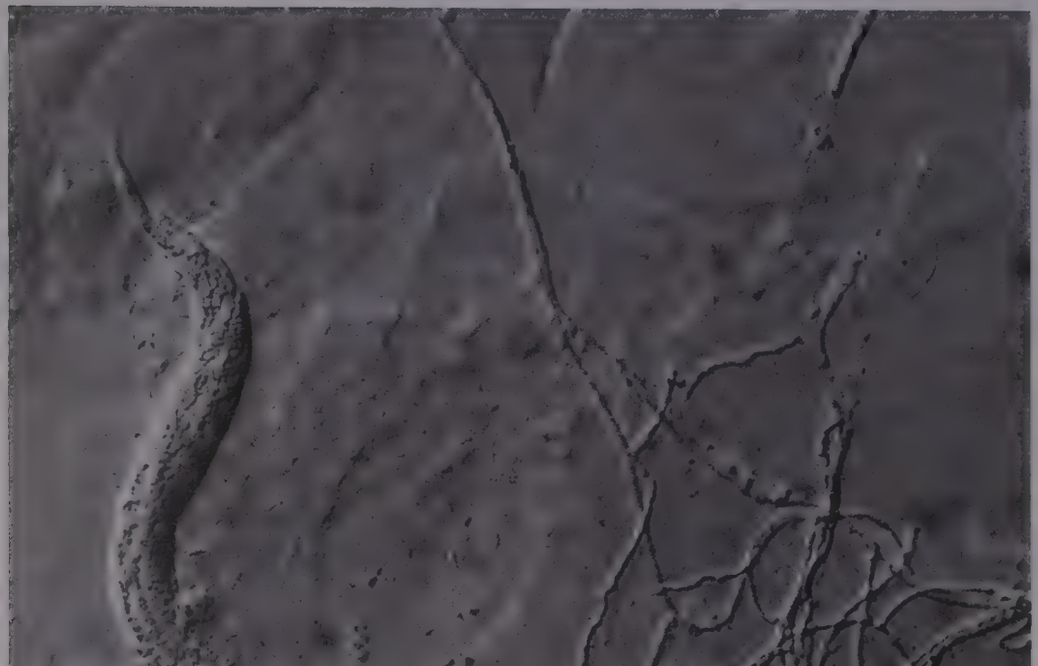
With hundreds of types of microscopic creatures in soil and decaying logs, fungi are not limited to nematodes or rotifers. Prey for fungal predators are legion. One of our most exciting finds came about by happy accident. Some of the bacteria we fed to our eelworms accidentally contaminated our fungus culture and grew into tiny colonies on the surface of the water agar. To our surprise, the hyphae of the oyster mushroom and the wood blewit attacked and destroyed the bacteria.

Scientists have long known that many fungi produce antibiotics that kill bacteria in their vicinity, but what we witnessed was something entirely different. The fungi appeared to recognize the presence and location of the bacteria and sent strands of hyphae in their direction. On contact with a colony, the fungi secreted enzymes that destroyed the bacterial cells and absorbed the products, just as they do with eelworms or any other multicellular organisms. Why would fungi attack bacteria? In the habitat of wood-rotting fungi, bacteria are one of the most prevalent life forms. More significantly, several bacterial species inhabiting decaying wood can fix nitrogen gas to form biologically useful nitrogen compounds. Preying directly on bacteria, therefore, might be a better way to survive in a nitrogen-poor environment than subsisting solely on nematodes, which are bacterial feeders. (Cutting out the middleman, so to speak.)

Another of my graduate students, Susan Madzia, has now discovered more than twenty species of mushrooms, normally

Captured by rings of the fungus Arthrobotrys *(magnified 750 times), this nematode worm, below, top, will be crushed as the nooses constrict. Below, bottom: Hyphae of the oyster mushroom (magnified 800 times) home in on an eelworm already paralyzed by toxin. Opposite page: Poisonous shaggy* Pholiota *mushrooms feed on both living wood and bacteria.*

Scanning electron micrograph by Nancy Allin and George Barron



Scanning electron micrograph by George Barron

associated with wood decay, that can attack and destroy bacterial colonies in the laboratory. We believe many more will be added to this list and that this phenomenon is probably common in nature. Among the bacteria-attacking fungi are species common in field and forest, including the shaggy mane, small puffball, orange *Mycena,* turkey tail bracket, and bird's nest.

The tactics of predatory fungi discussed here represent only a few among an enormously diverse array of strategies. (How do I kill thee? Let me count the ways.) Some fungi produce helicoid spores that screw into the esophagus during ingestion. There are zoosporic fungi that produce myriads of tiny swimmers that track down their moving victims by homing in on leakage products from body orifices. One fungus acts like a microscopic tapeworm; it fastens to the gut wall of a nematode and feeds on the food flow until it grows to completely fill the gut. Another species has fungal spores like grappling hooks; its incredibly sharp points impale rotifers on contact. Most remarkable of all, however, is the gun cell of *Haptoglossa mirabilis.* When triggered by contact with a rotifer or nematode, the fungus shoots a harpoon-shaped projectile through the wall of its victim. A hypodermic is then inserted and an infective spore pumped into the body. All in a fraction of a second.

For microbial life forms, life span is measured not in years or days but in hours or minutes. In soil or inside rotting stumps, dramatic scenes of life and death are played out every minute of every day. We have seen something of this microscopic mayhem in our laboratory dishes; now it remains for fieldworkers to return to the forests and probe what is really going on there. What we are unraveling is the complex interrelationship between unrelated groups of microorganisms in the ecosystem. This principle was well stated by the nineteenth-century evolutionist Alfred Russel Wallace when he wrote, "This vast and wonderful universe, with its almost infinite variety of forms, motions, and reactions of part upon part . . . has ever required and still requires the continuous coordinated agency of myriads of such intelligences." □

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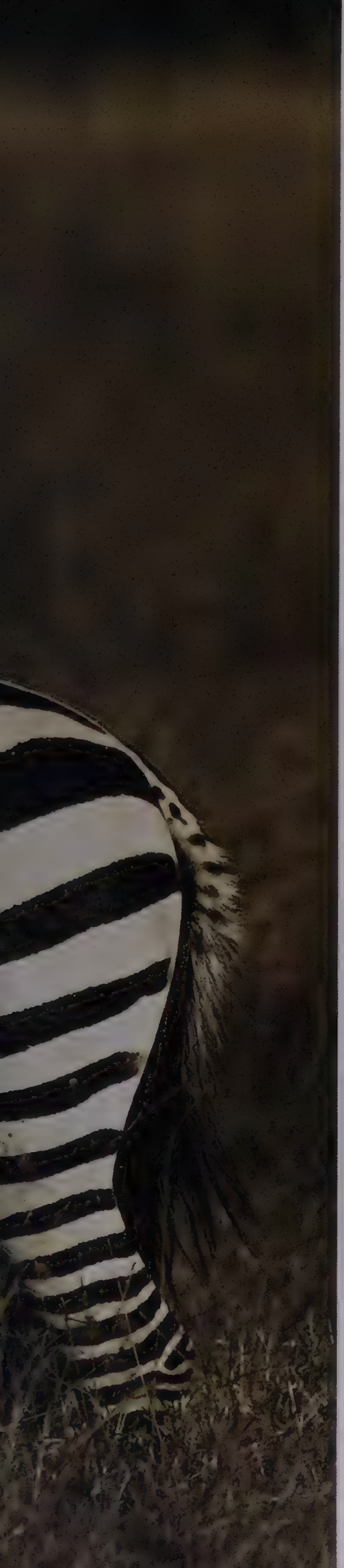


Unperturbed by its passengers, a Burchell's zebra pauses from grazing on savanna grasses in Kenya's Masai Mara Nature Reserve.
Peter Davey; ARPS

Tickling for Ticks

When oxpeckers looking for parasites scurry over zebras, the animals often appear to be mesmerized

by Randall Breitwisch

As the early morning sun warms the savanna of Masai Mara Nature Reserve in southwestern Kenya, a small herd of zebras—a stallion and his mares and foals—are already feeding on the rich grasses. I have the overwhelming feeling that I am watching organic eating machines. The zebras bite and chew without a pause, inching forward, clipping the grasses so close to the ground that their muzzles seem to sweep the savanna. The sounds of pulling, clipping, and chewing are relentless.

As I watch, several oxpeckers fly over the zebras, calling in unmusical notes. These birds are themselves a family, parents with two nearly independent fledglings. When they are about eighty feet overhead, they stop their direct flight, circle, and then quickly descend. Within seconds, they swoop onto the backs of the grazing zebras. I keep my eye on one animal. Then, something remarkable happens. The moment the bird lands on the zebra's back, the animal abruptly stops its mechanical feeding, lifts its head high, and stands still and erect. The brown, starling-sized bird begins to act like a huge probing insect. Looking for all the world like a flea wending its way across a forest of hair, the oxpecker skitters across the zebra's body. The oxpecker moves from back to flank, dips under the belly (where it hangs upside down), works down one leg to the hoof and up to the side, and completes its circuit on the back, where it perches and preens in the morning sun. Now for the first time, I can see that it is not a red-billed but a yellow-billed oxpecker, the more common species in Masai Mara.

Found throughout much of sub-Saharan Africa, except in dense forest, the two species of oxpeckers are most common on the savanna. Cavity nesters, they seek out large dead trees or trees with dead limbs in which woodpeckers have previously excavated nest holes. They are cooperative breeders, with one or more young from one season remaining with their parents to help raise the next season's offspring. During the nonbreeding season, small social groups roost in appropriate sites (even under the eaves of buildings), sometimes with species of starlings. The brood of two to three nestlings spend about a month in the nest hole, where they are fed by all group members. After fledging, they spend at least a month in their parents' care, at times begging and being fed while they perch on the backs of zebras and other savanna mammals.

This morning on the Masai Mara, the bird I was watching continued its zebra-back preening for a few minutes while the zebra retained its attentive posture, as if it knew just how to behave in this situation. But why should the zebra change its behavior to accommodate the bird? The oxpeckers seem to take the stillness for granted and go about their business unconcerned that their 600-pound perch might suddenly make a dangerous move. With impunity, the birds attempt to enter every orifice, to squeeze into every crease, cranny, and crevice on the surface landscape of a zebra. They are searching out and eating ectoparasites—blood-sucking flies and ticks (the British more aptly call these birds tickbirds). They may also remove dead tissue and maggots from wounds in the mammal's hide and occa-

Oxpeckers often "work" the whole animal. A zebra, below, obliges by raising its tail.

K. Ammann

sionally help themselves to a sip of blood from a cut.

Oxpeckers are entirely dependent on mammals. I have occasionally seen birds climb down a zebra's leg and hop onto the ground, where they may catch a few insects, but they soon jump right back onto the zebra. The birds are built for crawling across these animals' bodies. Their claws, similar to those of woodpeckers, are long, strong, and deeply curved, and their bills are designed for pecking, probing, and scissoring. Oxpeckers spend nearly all their waking hours on mammals; they court each other and even copulate on them. They also supplement the dried vegetation with which they line their nest holes with hair they have "clipped." I have watched oxpeckers snipping hair from the flanks of impalas, then flying off with their bills so full that they appear to have golden mustaches.

My strong impression is that oxpeckers like the company of mammals; in this part of East Africa they are found on zebras, impalas, giraffes, wart hogs, Cape buffaloes, and occasionally, Masai cattle. (Some researchers suggest that in areas

M. Reardon; Photo Researchers, Inc.

Red-billed oxpeckers glean ticks from an impala fawn, left. Growing animals can ill afford to lose blood to ticks. The Cape buffalo, below, is one of the oxpeckers' larger clients.

William Ervin

inhabited by both species of oxpeckers, each species displays preferences for different mammals. The yellow-billed may be found more often on sparsely haired mammals, such as Cape buffaloes. Both avoid densely haired mammals, such as waterbucks, but are found on rhinoceroses, giraffes, and a variety of antelopes, as well as wart hogs and zebras. I have never seen an oxpecker on an elephant.) On many occasions, I have watched a giraffe or a buffalo walk out of a riverine stand of trees and bushes, stride across the savanna, and disappear over the next low hill, while an oxpecker perched, immobile, high on its back, the bird's head pressed against the mammal's hide.

The oxpecker clearly benefits from such intimacy. But is this a case of symbiosis, or mutual benefit, in which the mammal also gains from the relationship? The extent of health benefits to the mammal is difficult to measure. To study this scientifically, we would need to prevent oxpeckers from cleaning mammals in a natural setting and then document the parasite loads on, and the health of, these uncleaned animals. This has not been done. However, Ben Hart, of the University of California at Davis, has reviewed some information involving domestic cattle that shows that a single tick can drink enough blood from a calf to decrease the calf's growth rate by more than a pound a year. The cost of a load of several ticks on a markedly slender antelope or zebra foal may indeed be substantial. While we do not yet have numbers, we do have observations of mammal behavior in the presence of oxpeckers. In general, these behavioral patterns suggest that the mammals not only tolerate but actively accommodate the birds' activities, altering their behavior to allow the birds to clean them most efficiently. I believe this accounts for the zebra's peculiar stillness, and that the pose is a signal to the bird to carry on its feeding and cleaning behavior. This brings us into poorly charted waters: communication between different species of animals. It is one of the aspects of the interactions between oxpeckers and large mammals that I find most interesting.

That morning on the savanna, I continued to watch the individual zebra with its perching oxpecker. When it had finished

preening, the bird hopped along the zebra's back toward its rump in such an exaggerated manner that it looked like it was bouncing. The exaggeration of this movement marks it as a display—a ritualized, stereotypical motion. I believe this display is meant for the zebra. Five or six hops and a second later, the bird perched on the zebra's rump. Still in its statuelike pose, the zebra raised its tail quickly and held it out behind its body. The oxpecker immediately scuttled down onto the hairless, black skin that surrounds the zebra's anal region and worked this area assiduously.

I have never darted zebras with tranquilizer-loaded projectiles, so I don't know the extent of the ectoparasite load in this region of a zebra's body. I do know that oxpeckers are keen to explore it. In more than two-thirds of the 134 instances I witnessed, the zebra responded by raising its tail when an oxpecker gave its hopping display. The only other time that a zebra lifts its tail is when it is about to defecate. Because they eat so much grass, zebras defecate often, but this tail-lifting behavior is rare on a minute-to-minute basis. I contend that a zebra's readiness to raise its tail when an oxpecker bounds down its back supports the hypothesis that bird and mammal are communicating.

If so, what other signals might fit into this repertoire, and how do mammals other than zebras communicate with the birds? Some large mammals, such as waterbucks and hartebeests, are quite intolerant of the oxpecker's activities and will repeatedly brush off or even run away from newly perched birds, dislodging them in the process. Other mammals, such as impalas, react differently in different circumstances. Sometimes, when an oxpecker lands on an impala and moves onto its head, the impala shakes its head violently, dislodging the bird. However, an impala whose body is being cleaned by an oxpecker will often place its nose gently right next to the bird, even bending its neck sharply to reach an oxpecker on its back. The bird then hops onto the impala's

Clem Haagner; Anthony Bannister Photo Library

Preferring a backbone to a branch, yellow-billed oxpeckers perch on a giraffe, left. Tick-ridden hairy bodies offer oxpeckers not only a foraging ground but also a social arena where they can meet mates, court, and even copulate. Oxpeckers can have a mesmerizing effect on young animals, like the wart hog below; an animal will sometimes sink to the ground while the birds work.

K. and K. Ammann

ace and begins to clean it. In such cases I ever saw an impala shake off a bird.

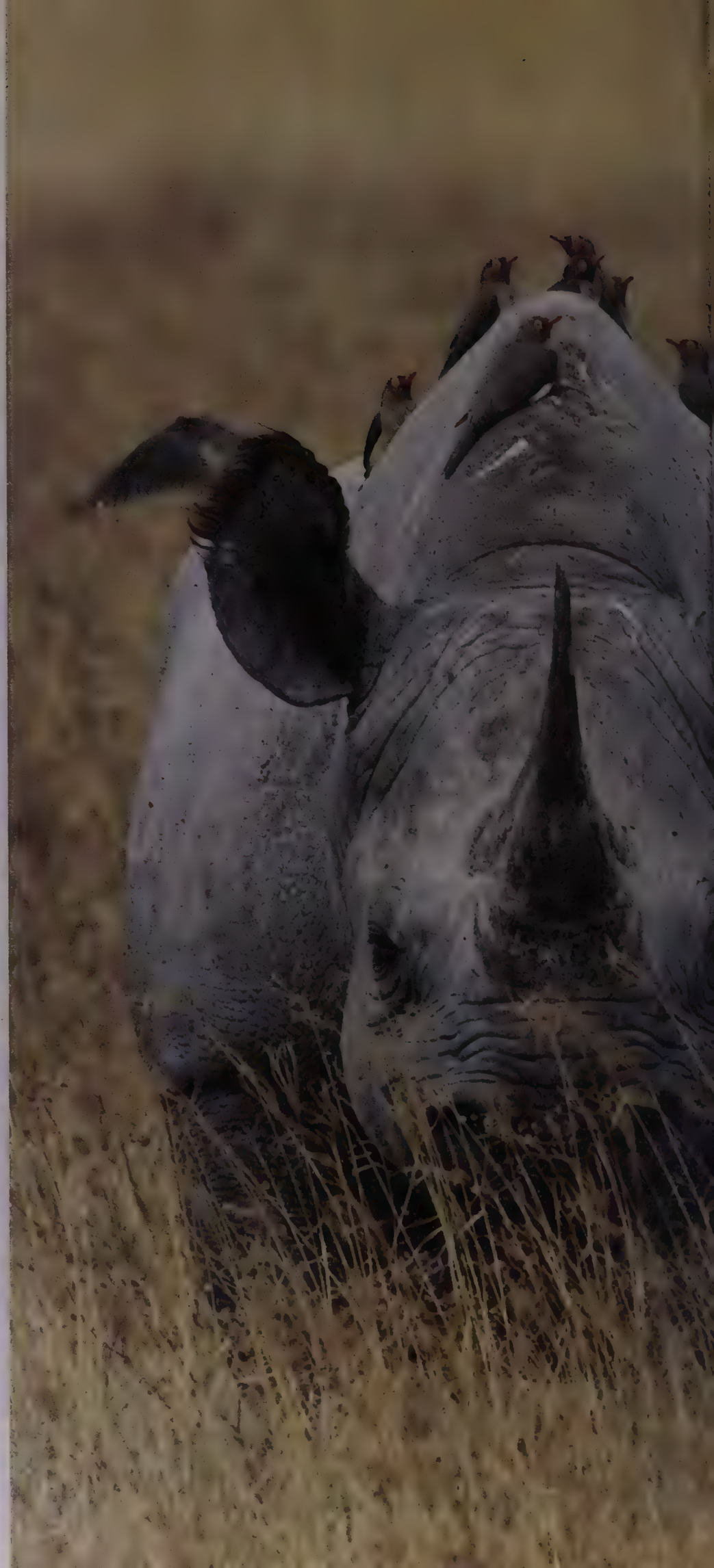
Like impalas, zebras do not always welcome foraging oxpeckers. Sometimes a ebra swings its head back to the place where the bird has landed as if to push it ff, and it frequently succeeds. The oxpecker either flies to another mammal or hifts to a new location on the same zera's body. Zebras may dislodge a bird our or more times, causing it to change eeding sites, and then seemingly give up, etting the oxpecker remain. The birds can e quite insistent on foraging in a particular location once they have found something of interest, and they may well be ritating as they bring claws and bill to bear on an animal's body. (Some researchers have even speculated that oxpeckers keep wounds open to "farm" a constant supply of maggots.) Sometimes a zebra appears to try to rid itself of a bird and then apparently surrenders. But could the attempt to disrupt the bird's activity be a way for the zebra to tell an oxpecker where to forage? If a zebra has an exceedingly irritating tick attached, say, between its forelegs, perhaps it uses certain actions to direct the oxpecker to that spot.

I continued to observe the small herd on the savanna even after the oxpecker flew from the individual I had been watching. This zebra maintained its rigid posture for a few more minutes before it resumed grazing. The animal appeared to be—and I use this word advisedly—hypnotized. The same language has been used by others in describing how some coral-reef fish look when their skin and mouths are being cleaned by wrasses, smaller fish that make a living picking ectoparasites from their "clients." George Losey, of the University of Hawaii, hypothesized that cleaner wrasses are able to engage in such a potentially dangerous activity as scouring the mouths of predatory fish precisely because they have evolved the ability to alter the client fish's motivational state. Something about that gentle nibbling at the skin's surface may be mesmerizing.

In Africa, I have seen various mammals respond similarly to the ministrations of oxpeckers. I've seen zebra foals, impalas, and even tough little wart hogs apparently lose their balance and gently drop to the ground when being cleaned by oxpeckers. To all appearances, they have fallen under an avian spell.

A final aspect of the peculiar relationship between oxpeckers and mammals involves alertness for potential danger. In some small areas of African parks, oxpeckers have become habituated to humans, but as a rule the birds are "flighty" and difficult to observe. They respond to approaching vehicles, to which most park visitors are confined, by giving alarm calls, scuttling to the far side of the mammals, then flying away before an observer can get close enough to record their behavior in any detail. Since the birds are in little direct danger from humans, why are they so quick to call and flee? I offer

A black rhino mother and calf share a flock of foraging oxpeckers. Known in some parts of Africa as "guards of the rhinoceros," oxpeckers have long been associated with this now endangered mammal.
Stephen J. Krasemann; Valan Photos



the following explanation: I believe that oxpeckers are honest in their dealings with mammals. The birds benefit from having their mammalian clients at ease in their presence. As barbers say about cutting the hair of small boys, it is difficult to hit a moving target. Abrupt moves on the part of the mammals could be hazardous. But grazing mammals need to be alert to possible attacks from diurnal predators, so they are naturally skittish and acutely responsive to noises, movements, smells—anything out of the ordinary. These same mammals may tend to relax more readily in the presence of oxpeckers if they instinctively rely on the birds to alert them to potential danger through alarm calls. An oxpecker can more efficiently exploit a relaxed mammal as a source of big, juicy, blood-engorged ticks. And a mammal with an oxpecker aboard becomes something of a sensory "superorganism," with the eyes of a bird, nose of a mammal, and the ears of both, a formidable early-warning system.

Said to be even more intimately involved with oxpeckers than the animals I have observed are both the African black and white rhinoceroses. In the Kiswahili language of east-central Africa, oxpeckers are called *askari wa kifaru,* "guards of the rhinoceros." The tragic decline in the populations of African rhinos prevented me from observing them. Land once roamed by wild mammals has been overrun by cattle, whose ectoparasite loads are largely eliminated by the practice of "dipping" cattle in pesticide baths. Probably as a consequence, the numbers of oxpeckers have also declined in recent years, and the birds have become locally extinct in some parts of Africa. Although oxpeckers are not endangered, their local disappearance has led to efforts to reintroduce them to some parks, especially in South Africa and Zimbabwe. Behaviorists have only recently begun to observe in earnest the relationship between oxpeckers and wild mammals, and detailed reports have not yet even entered the scientific literature. But unless conservation measures save the main players, we may witness not only the animals' extinction but also that of a most intimate, and intriguing, relationship. □

First Writes

by John R. Alden

Today, it is difficult to imagine a world without written words. Yet in the long process of human evolution, writing is a recent invention. The earliest known tablets date to just over 5,000 years ago, and societies where the majority of adults were literate probably only appeared within the last 200 years. Although we know roughly when and where writing first appeared, the question of "how" has all too frequently been addressed with scientific-sounding versions of a just-so story. In contrast, *Before Writing* offers a thoroughly researched and carefully argued attempt to unveil the beginnings of the device that made history possible.

Writing systems developed independently in at least three regions—Mesopotamia, China, and Mesoamerica. Although the Egyptian and Indus Valley writing systems may have been derived from the Mesopotamian, they differ enough to be treated as independent systems. The Andean quipu system, where counts of various items or commodities are recorded by arrangements of knots on strings, represents yet another kind of incipient writing. Because each of these systems appeared under different circumstances and each developed in response to the needs of a particular social elite, no single explanation for the origins of writing will ever be found. But individual instances can be studied and understood. Here Denise Schmandt-Besserat, a professor of art and archeology at the University of Texas in Austin, examines the appearance of writing in Mesopotamia.

Writing, she argues, developed from the practice of using molded clay "tokens," or "counters," as an accounting device for keeping track of food and other basic commodities of prehistoric life in the Near East. Sometime about 3500 B.C., the people of southern Mesopotamia began sealing collections of such counters inside clay balls and using these "envelopes" to record and validate information on economic activities. Because opening the clay balls scattered their contents (thus destroying the very information the envelopes were made to preserve), people began recording the number of tokens inside the balls by making impressions of the tokens on the surface of the wet clay envelopes.

"At first," writes Schmandt-Besserat, "the impressed notations were ancillary to the counters, but in the course of time they challenged and eventually supplanted them. This occurred when solid clay tablets bearing impressed signs replaced the hollow envelopes holding tokens." Instead of repeating the message communicated by the tokens, the impressions became the message.

Substituting two-dimensional signs for three-dimensional tokens was not as straightforward as it sounds. Each token represented some number (usually one) of a specific thing—a jar of oil, a large or small measure of grain, a piece of cloth-

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BEFORE WRITING: FROM COUNTING TO CUNEIFORM, vol. 1, by Denise Schmandt-Besserat. *University of Texas Press, $60.00; 304 pp., illus.*

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ing, or a particular kind of animal. The impressions made by the tokens, however, couldn't contain as much information as the tokens themselves, and they would have been more difficult to interpret. When people began supplementing or replacing the token impressions with inscribed signs, writing was invented.

What evidence supports this intriguing explanation? It begins with a collection of 8,162 tokens from some 115 Near Eastern sites, "studied firsthand in thirty museums in fifteen countries." Tokens have been found from Israel in the west to eastern Iran in the east, from as far north as southern Turkey and as far south as the head of the Persian Gulf. Indeed, "whenever modern excavations were carried out in a Near Eastern site of the eighth to the fourth millennium B.C., they usually generated a crop, large or small, of counters."

For Schmandt-Besserat, a token is any small, geometrically shaped object of fired clay (or more rarely, stone). Typically, these are between a half and one and a half inches long. She defines 16 types of tokens (cones, spheres, disks, cylinders, tetrahedrons, ovoids, rectangles, triangles, bicones, paraboloids, bent coils, ovals, vessels, tools, animals, and miscellaneous) and some 500 subtypes based on variations in shape, size, decoration, or marking. She also divides the assemblages of tokens from different sites into two classes, "plain" and "complex." The plain assemblages include mainly cones, spheres, disks, cylinders, and tetrahedrons, and the tokens in these collections are only rarely marked. Complex assemblages contain a wider variety of types and subtypes and typically include tokens that are perforated or marked with incised lines, punctations, pinches, notches, appliqué, or paint.

Tokens appear as early as 8000 B.C. and are found in deposits dating to as late as 1500 B.C. In terms of social context, the plain tokens appear in some of the world's earliest villages, are used more or less continuously through the time of the first cities (4000 to 3500 B.C.), and gradually fall into disuse in the literate civilizations of the third and second millennia B.C. Complex tokens first appear about 4400 B.C. in southern Iraq and are found almost exclusively in large urban or proto-urban settlements dating to the years between 3800 and 3000 B.C. Significantly, tokens of all sorts become rarer after the appearance of writing, and the complex tokens virtually disappear.

The most crucial support for Schmandt-Besserat's theory comes from the sealed clay envelopes. She has tracked down 130 whole and 70 fragmental examples from ten proto-literate sites and has information on the tokens contained in some 42 of these objects. Only five of these envelopes were discovered whole and opened by archeologists. Twenty-eight were broken in antiquity, five groups of tokens came from one or more crushed

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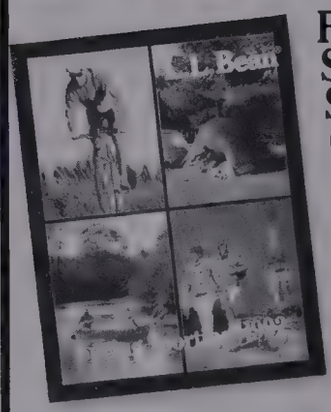

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envelopes, and the contents of three unbroken envelopes have been scanned by X-ray. (Surprising as it seems, archeologists really have left most of the whole envelopes unopened.) As data sets go, this isn't much, but the finds do show that the envelopes contained both simple and complex tokens and that in the four examples of whole envelopes with token impressions on them, the number of impressions on the outside is the same as the number of tokens contained within.

Finally, there are the tablets. The earliest of these are impressed with signs that look almost exactly like the impressions of the most common tokens, and like the majority of the clay envelopes, these early tablets typically have impressions of stamp or cylinder seals, as well as impressed signs. Most of these "impressed tablets" come from the sites of Susa (in lowland Iran) and Uruk/Warka in southern Iraq; they frequently appear in direct association with clay envelopes and come from deposits dated to between 3500 and 3100 B.C.

After some 200 to 400 years, pictographic signs begin to appear along with the impressed symbols. Intriguingly, two separate pictographic scripts developed. Schmandt-Besserat limits her discussion to the proto-cuneiform script that developed in Warka and southern Iraq, a script in which some of the earliest inscribed signs seem to derive from the shapes and markings found on complex tokens. But there is a second script, proto-Elamite, which appeared a bit later than proto-cuneiform at the site of Susa and a series of contemporaneous settlements in southwestern and southern Iran. And while this second script employs number signs and systems that are very similar to those used in proto-cuneiform, its repertoire of pictographs is distinctly different.

Schmandt-Besserat's explanation of the origins of Mesopotamian writing accounts for many of the patterns evident in the archeological record. It is not, however, universally accepted. One concern involves the quality of the data she is working with. Many of the tokens identified here come from badly excavated or inadequately recorded contexts. These small, earth-colored objects are easy for excavators to overlook and are unusual enough in most sites so that the numbers found probably reflect the luck of the dig more than statistically reliable patterns of distribution. Tokens that were only sun-dried or poorly fired would be unlikely to survive, and the smaller and simpler classes of token are surely underrepresented in publications and museum collections. In my opinion, however, the author deals

with these problems in a reasonable, responsible way.

Having studied Near Eastern archeology and worked on Near Eastern archeological sites, I would disagree with some of the details and arguments presented here. The envelope from Shahdad, a site in central Iran, is decorated with circular marks but has no seal impressions. I would hesitate to call the Uruk-period seals and sealings from Uruk, Susa, Tello, Chogha Mish, and Habuba Kabira "exactly alike," and I am not convinced that bevel-rim bowls were used to distribute rations and can thus be considered "administrative artifacts." The author also overstates the degree of association between temples and complex tokens, envelopes, and tablets, particularly at the Iranian site of Susa. Still, I don't believe such relatively minor points cast any serious doubt on her argument that token impressions were the basis for the earliest Mesopotamian writing.

There are, however, two major problems affecting Schmandt-Besserat's broad reconstruction of how writing evolved. First, there is no evidence that the tokens found in early agricultural villages were used to record economic information. Indeed, it would be unusual for people in such small and generally egalitarian communities to keep permanent accounts of ownership or debts. Other archeologists have suggested that tokens might have been used as toys, amulets, game pieces, beads, fasteners, or weights. Given their presence in so many regions and so many different kinds of sites for more than 5,000 years, it seems likely that these little objects were used in a multitude of ways in different Near Eastern villages.

The second problem involves stamp and cylinder seals and the ways the symbols used on these devices relate to the development of Mesopotamian writing. Although the author admits that "it is likely that tokens were closely connected to stamp seals, which were developed in the seventh millennium (B.C.)," she never explores the connections between seal impressions and preliterate accounting systems in any depth. Because the majority of the clay envelopes and impressed tablets also have seal impressions, it would seem that the impressed signs and seal impressions convey related kinds of information for the people using these accounting devices. Furthermore, in the case of proto-Elamite, a significant number of the signs found on the pictographic tablets also appear on the seals. Complex tokens seem to represent one Near Eastern symbol system relating to the origins of writing, but that was not the only such system, and it may not even have been the most important.

The evidence presented in this book supports an important general principle that is surely familiar to most readers of this magazine. Human inventions, like biological adaptations, rarely appear out of the blue. Instead, they typically involve the modification of an existing device or structure to serve an expanded function. In *Before Writing,* Denise Schmandt-Besserat argues that the earliest writing in the Near East arose when a well-established accounting system involving small clay tokens was modified to serve the changing needs of an emerging religious elite. The details of this proposal may have to be changed as better archeological evidence accumulates, but that will not alter the importance of Schmandt-Besserat's work. For readers who want to delve deeply into the nitty-gritty origins of writing, this book is the place to start.

An archeologist and free-lance book reviewer, John R. Alden is currently working on tracing a segment of the Inca road in northern Chile.

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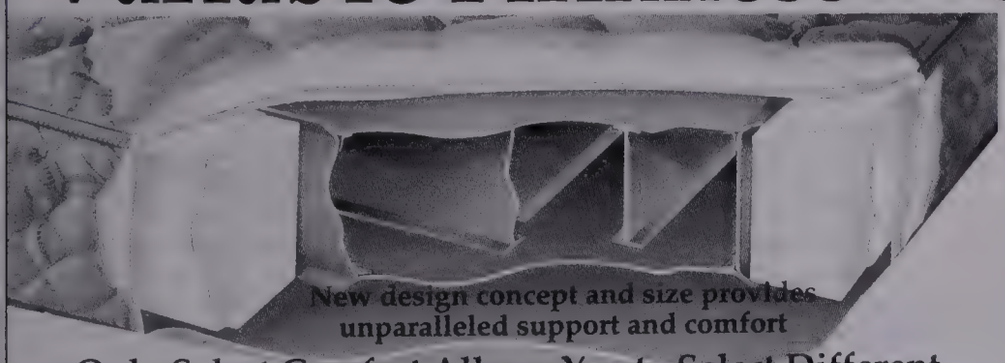

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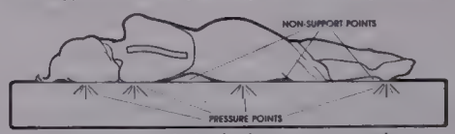

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Here Comes the Sun

by Gail S. Cleere

The vernal equinox occurs on the 20th of this month at 3:48 A.M., EST, marking the first day of spring in the Northern Hemisphere and days and nights of roughly equal length. At this time, the sun lines up with a specific place in the sky (where the celestial equator crosses the ecliptic) called the vernal equinox. Also called the first point of Aries, the vernal equinox is the fundamental reckoning point in the sky for all celestial objects, the equivalent of the place off the west coast of Africa in the Gulf of Guinea where longitude and latitude are zero degrees.

In ancient cultures, the equinoxes and the solstices were the four great hinges upon which the solar year revolved. On the dates of the year's equinoxes, the sun rises precisely in the east and sets precisely in the west—an observation that allowed our ancestors to determine the exact direction of these cardinal points. On the solstices, the sun reaches its highest and lowest points in the sky. Alignments to the sunrise or sunset points along the horizon on these dates were not at all uncommon in the ancient world.

Egypt's great pyramids at Giza were built with their sides aligned precisely to the north, south, east, and west. On the equinoxes, anyone looking westward from the Valley Temple at Giza would see the sun setting along the south side of Khafre's pyramid and disappearing into the horizon. In the 1970s, Herbert Ricke, of the Swiss Archaeological Institute, suggested that the Sphinx was not placed to guard the Giza necropolis, as earlier Egyptologists had surmised, but was a temple to Ra, the sun god. In 1986, Mark Lehner, an archeologist and Egyptologist at the Oriental Institute in Chicago, found that on the day of winter solstice, the setting sun traces an outline along the Great Sphinx's head. And on the day of summer solstice, seen from the Sphinx, the sun sets directly between the silhouetted images of Khufu's and Khafre's pyramids—forming the Egyptian hieroglyph *akhet* (a circle between two triangles), meaning "places where the sun rises and sets."

In Egypt, the importance of aligning things with the sun continued long after the pyramid construction of the Old Kingdom ended. The tomb of Tutankhamen, the boy pharaoh, was built more than 1,000 years after the last pyramid at Giza was completed. The four alabaster jars containing the pharaoh's vital organs were arranged with their portrait heads facing each other exactly in the sacred east and west directions. An inscription was found that read: "All protection of life is behind him, like the sun."

Celestial alignments to the equinoxes and solstices are not peculiar to a single society but crop up around the world at various times, sometimes simultaneously in two very separate societies. Stonehenge in England, which was going up about the same time as Giza's first pyramid, was constructed with alignments to the sun's rising point on specific days of the year. Across the Atlantic, in A.D. 300, the Maya built three temples facing a pyramid at Uaxactún in Guatemala. If one stands at the pyramid on the equinoxes, the sun rises over the central temple. On the solstice dates it rises over the other temples, respectively. The American Plains Indians constructed what we call medicine wheels, which have nothing to do with medicine but mark the solstice sunrise and the rising of other stars important in their culture.

Although we don't know the full significance of many of these ancient monuments, we have determined their astronomical significance. They reveal a profound knowledge of the heavens and an equally profound reverence for the cyclical order of nature.

The Planets in March

Mercury reaches its greatest elongation east of the sun on the 9th, giving us a chance to spot the planet in the west in the twilight glow just after sunset. This happens to be a very favorable elongation for observers in the northern latitudes. Because of the steep angle of Mercury's path, the planet will be higher in the sky than usual (about 10 degrees above the horizon). On the 5th and 6th it will appear next to a thin crescent moon. By the 26th, however, elusive Mercury moves between the sun and the earth, reaching inferior conjunction.

Venus is low in the predawn southeastern sky this month. Its more rapid eastern movement carries it away from Mars and Saturn. On the 1st, a waning crescent moon hovers just above the three planets—a fitting celebration of Venus' first visitor from planet Earth, the Soviet *Venera 3* spacecraft, which landed on this day twenty-six years ago. The high pressures of the dense Venusian atmosphere crushed the craft on its descent to the planet's surface.

Mars is a faint morning object this month. On the 6th, the red planet is in conjunction with Saturn. In the southeastern predawn sky, Mars passes less than half a degree below Saturn.

Jupiter is the pride of this month's evening skies and can be seen in the constellation Leo, just to the east (left) of the bright star Regulus. Jupiter reached opposition at the end of February and now ascends in the sky as the sun sets, and sets as the sun rises. In the predawn hours of the 17th, a nearly full moon passes by just below the giant planet.

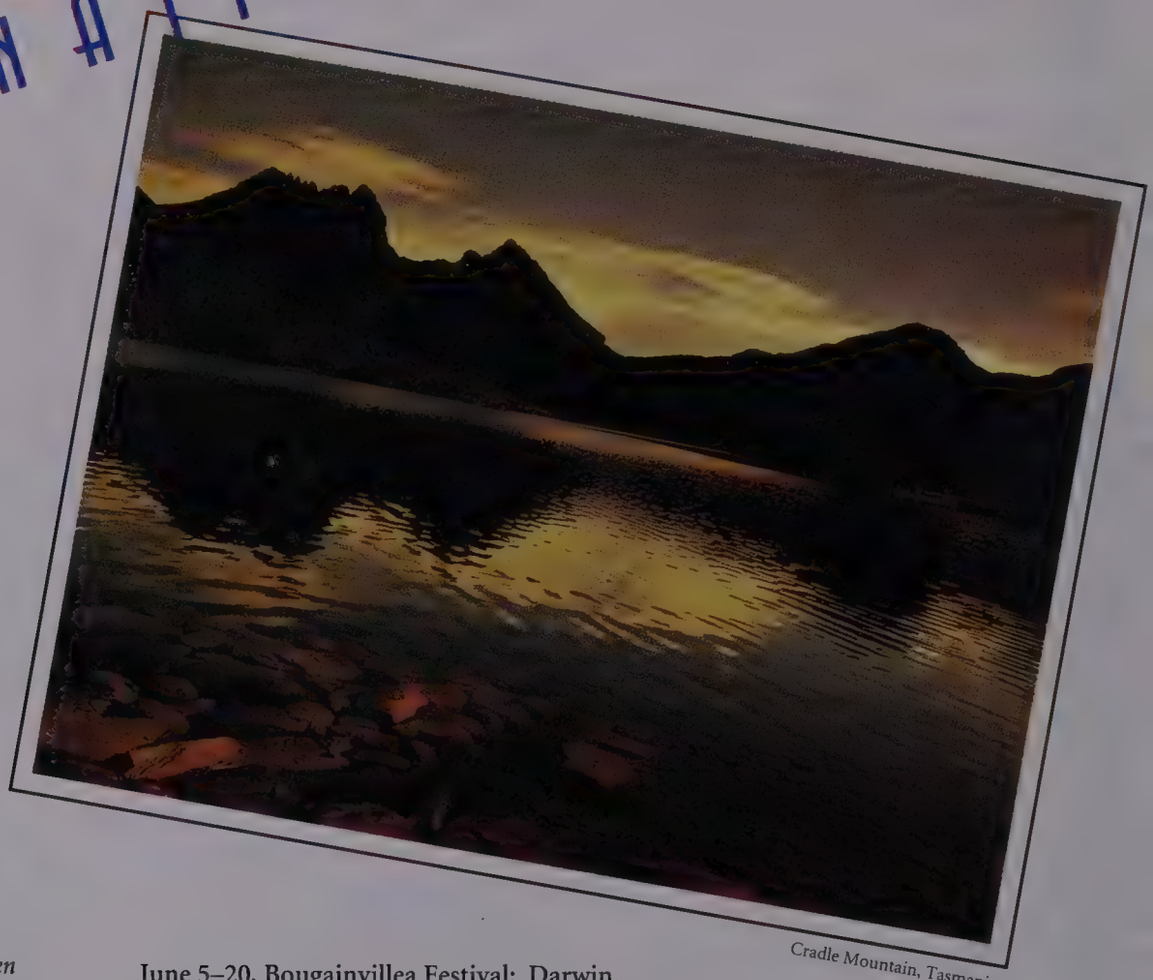
Saturn lies amid the dim stars of Capricornus above the eastern horizon and can be seen in the morning twilight.

Uranus and **Neptune** rise a good three hours before the sun and are well placed for observing in Sagittarius in the dark hours before sunrise. These two planets are never more than 2 degrees apart all year. On the 27th, Mars, Saturn, Uranus, Neptune, and the waning moon create quite a scene in the predawn southeastern sky. Binoculars and a sky map from one of the popular astronomy magazines are essential in spotting these distant planets.

The **Moon** is new on the 4th at 8:22 A.M., EST; reaches first quarter on the 11th at 9:36 P.M., EST; is full on the 18th at 1:18 P.M., EST; and reaches last quarter on the 26th at 9:30 P.M., EST.

Gail S. Cleere writes on popular astronomy and is a founding member of the International Dark Sky Association, an organization dedicated to preserving the skies for astronomy.

EXOTIC DESTINATIONS



Cradle Mountain, Tasmania

The exotic destinations of the world provide the traveler with endless sights and magnificent scenery, but the most lasting impressions are often those derived from immersing oneself in the local culture. The following cultural events occurring in Pacific and Asian countries from April through December offer unique opportunities for visitors to get to know the people and cultures of the places they visit.

COLORFUL AUSTRALIA

April 10–21, Royal Show: Sydney.
This is one of the premier shows in Australia, with a horse show, dressage events and agricultural events.

April 13–14, International Dragon Boat Festival: Sydney.
Large, ornate rowing boats compete in Darling Harbor, with teams from different countries participating.

June 1–8, Western Australia Week
Week-long celebration of the foundation of the state with various celebrations and festivals.

June 5–20, Bougainvillea Festival: Darwin.
Events highlighting the unique and harmonious blend of diverse cultures that make up the city.

July, Cape York Aboriginal Dance Festival: Laura.
Features dance groups from many of the Aboriginal communities.

July 3–4, Alice Springs Show Day
Annual show with historical and agricultural themes.

July 23–25, Royal Darwin Show
Includes agricultural displays, arts, crafts and other entertainment.

September 10–26, International Festival of the Arts: Melbourne.
Variety of opera, dance, theater, music and visual arts events.

September 25–October 4, Warana Festival: Brisbane.
The annual festival of this city, which begins with a parade offering pomp and pageantry. The festival also includes the performing, visual and literary arts.

December 1–March 1, 1993, Biennale of Sydney
Major international arts event featuring visual arts and performance, public projects and many special events.

COLORFUL HONG KONG

April (tba), Ching Ming Festival
This Confucian festival is the first of two occasions during the year that take place to honor the dead. Ancestral graves are visited, swept, washed repaired and painted and offerings of food, flowers and money are made. This festival also celebrates the coming of spring.

April (late) or May (early) (tba), Tin Hau Festival
This festival of the "Queen of Heaven" and "Goddess of the Sea" reminds one of Hong Kong's close links to the sea. Whole communities of Hong Kong's fisherman converge to pay homage to their protectress, their majestic junks festooned with brightly-colored clan banners.

May (tba), Bun Festival: Cheung Chau Island.
A ferry ride away from downtown Hong Kong is a most colorful and unusual

festival, with 70-foot towers made entirely of small pink and white buns erected in the courtyard of the Pak Tai Temple. The consecrated buns are then distributed to visitors and townspeople for good luck.

May (late) or June (early) (tba), Tuen Ng (Dragon Boat) Festival

"Tuen Ng" is a major cultural event, as dragon boats dash through the water urged on by drums and the roar of the crowd. The races commemorate the death of statesman–poet Ch'u Yuen, who drowned himself in the Mi Lo River in protest against a corrupt government.

June (tba), International Dragon Boat Festival Races

August (late), Festival of Hungry Ghosts

An evening walk through Hong Kong's streets and alleys may reveal the fascinating ritual "Yue Lan," a type of Chinese halloween, when offerings of food and carefully crafted paper replicas of money and other small personal necessities of life are burned by the roadside to appease restless spirits.

September, Mid-Autumn Festival

One of the most magical of all Hong Kong's annual celebrations, marking the occasion when the moon is at its fullest and brightest and also celebrating the year's harvest.

COLORFUL INDIA

May 11, Pooram Festival: Trichur, Kerala.

This festival honors the god Shiva. Magnificently decorated elephants carry ceremonial umbrellas and are fanned with peacock feather whisks as they parade around the temple to the sound of traditional musical instruments. In the evening, there are spectacular fireworks displays.

August 3, Naga Panchami: Southern India.

Snakes are considered immortal by orthodox Hindus and on this day, milk and flowers are offered to live cobras and at snake shrines. Hundreds of snakes are released and worshippers pour milk over themselves to ensure lifelong immunity to snakebites.

August 31, Ganesh Chaturthi: Bombay and elsewhere.

Another major Hindu festival celebrating Ganesh, the elephant-headed god of wisdom. Different areas vie to produce the biggest and most impressive idols; thousands of processions converge on Chowpatty Beach, bringing their images with them for immersion.

October 25, Diwali (Deepawali): Nationwide.

This "light festival" is a major holiday, symbolizing the lifting of spiritual darkness; houses are brightly lit with lamps and firecrackers are set off. It is also the first business day of the new year when old books are closed, new accounts are opened and there is a "fresh beginning."

November 7–10, Pushkar Mela: Lake Pushkar, Rajasthan.

This fair, a major tourist attraction, is held annually on the banks of the lake and includes camel and cattle fairs, and camel races.

COLORFUL NEW ZEALAND

April 11–20, Royal Easter Show: Auckland.

April 18–19, Highland Games: Hastings.

June 11–13, National Fieldays: Hamilton.

This agricultural and farming display is known as the best of its kind in the world and attracts many international visitors.

July 11–19, Winter Festival: Queenstown.

Sheep dog races and polar plunges in alpine lakes are among the events visitors are invited to watch. The highlight is a ski competition on the slopes of Coronet Peak. The evenings include concerts, dances and a Miss Snow Queen contest.

September 25–27, Blossom Festival: Alexandra.

This picturesque South Island town honors spring with a Mardi Gras. The highlight of this longest running festival in New Zealand is a parade of flower–bedecked floats and

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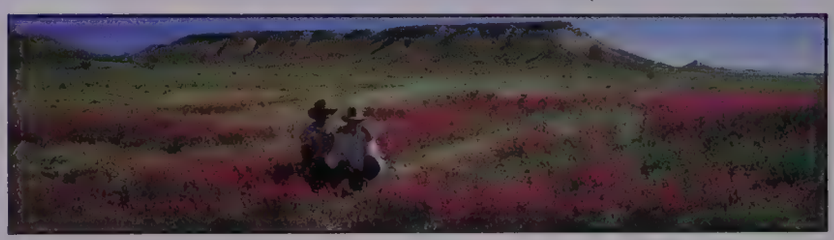

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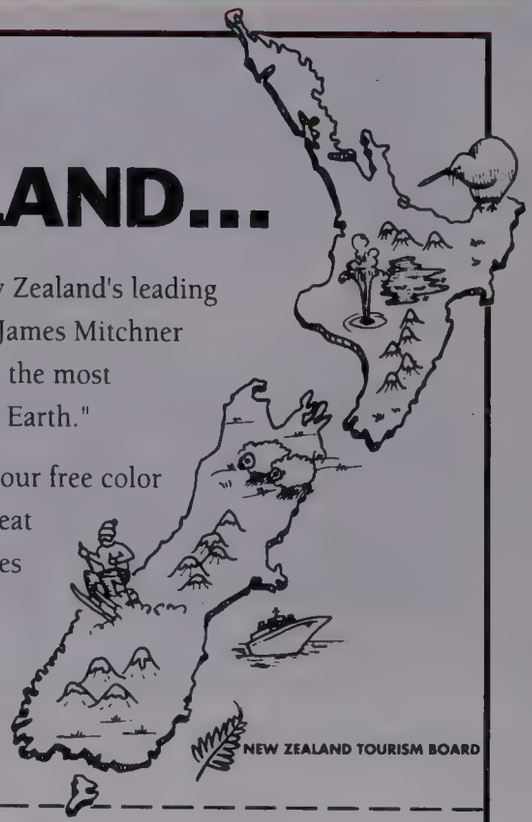

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the crowning of the Festival Queen.

November (mid), Otago Goldfields Celebration

The communities of Dunedin, Lawrence, Roxburgh, Fruitlands, Alexandra, Clyde, Arrowtown, St. Bathans, Macraes and Palmerston all take part in this 10–day cycle of celebrations. Festivities include rides on "The Gold Coach", picnics, billy tea served by women in period costume and gold panning.

COLORFUL PAPUA NEW GUINEA

June, Frangipani Festival: Rabaul.

This festival commemorates the first flowers to blossom after the 1937 eruption of Matupit.

August, Marborasa Festival: Madang.

This cultural show features dancing, choirs and bamboo bands.

August 21–23, Highlands Show: Mt. Hagen.

The fantastic yearly gathering from all over New Guinea, during which the men compete in the famous singsing contest; the dancers are brilliantly costumed and painted.

September 9–11, Eastern Highlands Show: Goroka.

Held every two years, this major singsing event attracts clan groups from throughout the region.

September 14–16, Hiri Moale: Port Moresby.

A great Papuan festival to commemorate the Hiri trading voyages. There is a canoe race in the harbor and a Hiri Queen contest.

September 16, Independence Day: Nationwide.

This is a great time to visit; there are many festivals and singsings throughout the country.

October, Morobe Annual Cultural Show: Lae.

This features singsing groups from the nearby valleys and islands.

COLORFUL SINGAPORE

May 17, Vesak Day

This public holiday commemorates the anniversary of Buddha's entry into Nirvana and is celebrated by all Buddhist temples. The day is spent in prayer and meditation; captive birds are given their freedom and candlelight processions are held in the evening.

June 14–15, Dragon Boat Festival: Marina Bay.

This colorful regatta is a spectacle of

flashing paddles, churning water and the beat of drums, with competitors from Australia, New Zealand, Europe, throughout Asia and the U.S.

June 1–30, Singapore Festival of Arts
A month–long cultural extravaganza featuring international music, dances, drama, mime, operas and experimental art forms.

August 9, National Day
This is a major public holiday, marking the anniversary of independence, observed with a parade, cultural performances processions of decorated floats and fireworks. Throughout the month of August there are various carnival celebrations.

September 11, Mooncake Festival
A charming festival held when the moon is believed to be at its fullest. Lantern–making contests are held and processions of children bearing lighted paper lanterns form part of the picturesque celebrations.

October 15, Thimithi Festival: Sri Mariamman Temple.
This spectacular fire–walking festival honors the purity of the goddess Duropadai; participants believe that as long as they remain pure in mind and soul they will not be harmed.

October 24, Deepavali
An exciting festival of lights during which Hindus celebrate the triumph of light over darkness and good over evil by festooning their temples with lights and garlands.

November 17–January 2, Christmas Sharity Light-Up
A very festive occasion in Singapore when the city is ablaze with colorful lights and endless activities lure visitors from far and wide.

COLORFUL TAHITI

May–June (3 weeks), Ta'Upiti O Papeete (Papeete Festival)
This three–week celebration includes rides, games, contests, singing and dancing, as well as fireworks and festival events.

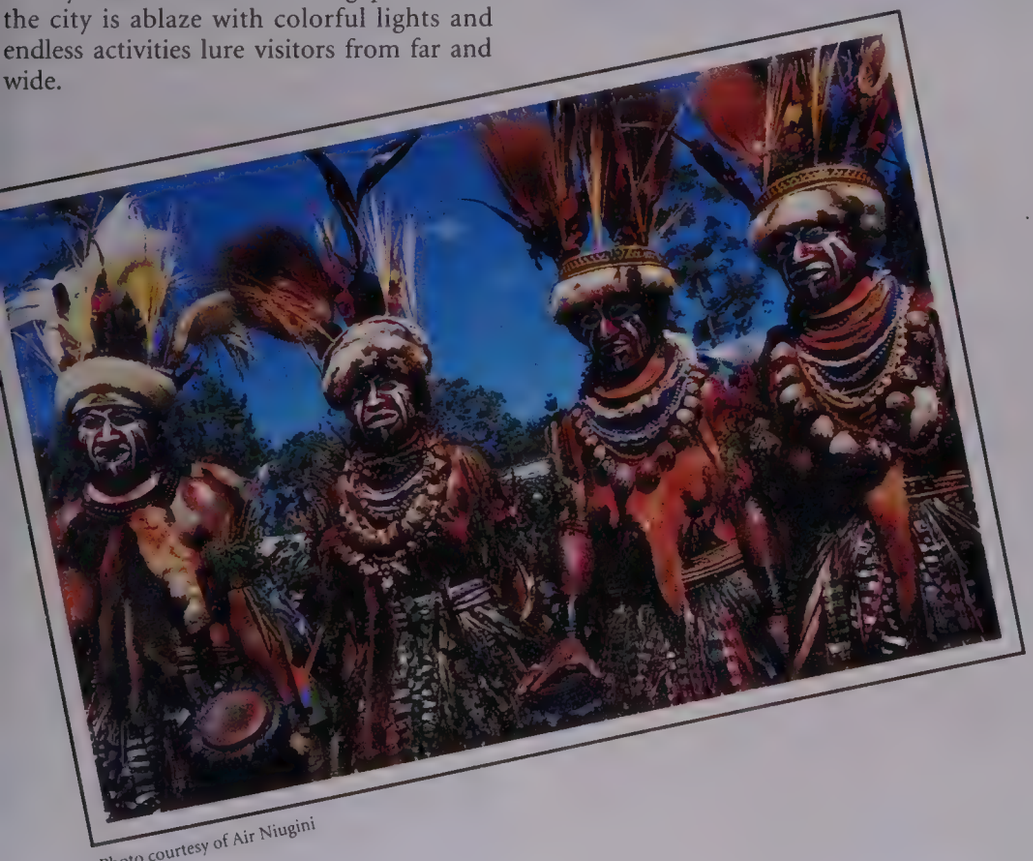
July (3 weeks), Heiva I Tahiti: Nationwide.
During this, the most important festival of the year, Tahiti is alive with cultural and sporting events, centered in Papeete. People gather from around the world to witness such events as outrigger canoe races, javelin throwing, traditional costume making, and fire walking. In addition, there are song and dance competitions and religious and cultural exhibits and events.

July 14, Bastille Day: Papeete.
France's national holiday is celebrated with an exciting parade, many parties and an all–night ball.

July (mid), 11th Tahiti International Pro-Am Golf Open: Olivier Breaud Golf Course, Atimaono.

July–August, Mini Festivals
Following the Heiva I Tahiti festivities, the winning groups of singers and dancers compete further over several nights at several of the top hotels in Tahiti, Moorea and Bora Bora.

September (late), 15th Floralies
This, the largest flower show of the year, is presented as an annual tribute to Tahiti's "Grandfather of the Trees," American Harrison W. Smith.



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October 28–November 2, 5th Annual Stone Fishing Ceremony: Taha.
Thousands attend this festival, which features singing and dancing, artisan exhibits, canoe races, sporting events, and an "Umu Ti" fire walking ceremony. The events come to a grand finale with the presentation of a huge Tahitian feast.

COLORFUL THAILAND

April 12–14, Songkran Festival: Nationwide.
The traditional Thai New Year celebration which can last up to one month. Religious merry–making, pilgrimages, parades, dancing and good–natured water throwing.
May 14, Royal Ploughing Ceremony: Bangkok.
This is based on an ancient Brahman ritual, celebrating the beginning of the rice–planting season. Various colorful ceremonies are conducted to ensure an abundant crop.
August 12, The Queen's Birthday: Nationwide.
Celebrated throughout the country, this important public event is a national holiday, and government buildings are decorated with colored lights.
September 12–13, International Swan Boat Races: Bangkok.
November 7–9, Loi Krathong: Sukhothai. (Celebrated Nov. 8–10 in Chiang Mai and in Ayutthaya.)
Thailand's loveliest festival is a Buddhist holy day, believed to have originated some 700 years ago in Sukhothai. Under the full moon, Thais float small lotus-shaped banana leaf boats containing a lighted candle, glowing incense, a flower and a small coin to honor the water spirits and to wash away the previous year's sins.
November 21–22, Elephant Round-Up: Surin.
Exciting displays of elephant hunts, demonstrations of intelligence, strength, gentility and obedience and the spectacular reenactment of a war elephant parade.
December 5, The King's Birthday: Nationwide.
Celebrations similar to those conducted for the Queen's birthday are planned.

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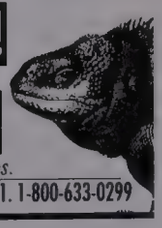

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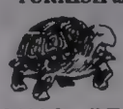

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The following new rates are effective with the April 1992 issue: $3.55 per word; 16 word minimum. *Display classified* is $390 per inch. All advertisements must be prepaid. Rates are not structured for agency or cash discounts. All advertisements are accepted at NATURAL HISTORY's discretion. Send check/money order payable to NATURAL HISTORY to: The Market, NATURAL HISTORY Magazine, Central Park West at 79th St., New York, NY 10024. Direct any written inquiries to Eileen O'Keefe at the above address. Please include your personal address and telephone number, issue preferred, and suggested category. Deadline—1st of the month, two months prior to cover date (the January issue closes Nov.1). Camera-ready art is required for display ads. A tearsheet or copy of the page with your ad will be sent upon publication.

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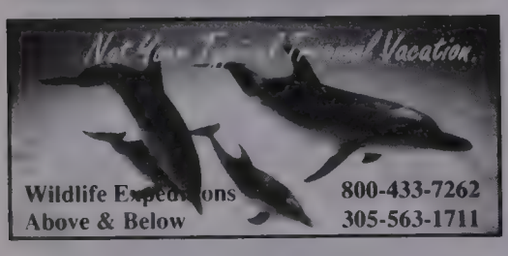

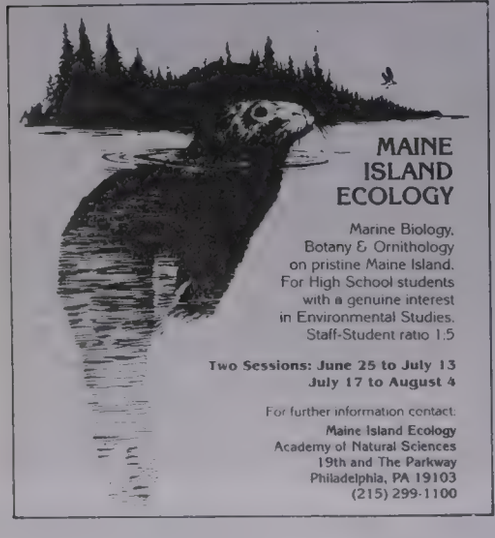
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AT THE AMERICAN MUSEUM

MAN AND NATURE LECTURE

Edward O. Wilson, the Frank B. Baird, Jr., Professor of Science and curator of entomology at Harvard University's Museum of Comparative Zoology, will present the 1992 Mack Lipkin Man and Nature Lectures at the American Museum of Natural History.

On Monday, March 2, Wilson will discuss the implications of the accelerating extinction rate, which threatens to destroy myriad plant and animal species at a time when biodiversity is at one of its highest points in our planet's history. On Tuesday, March 3, Wilson's topic will be the colonial adaptations that have enabled ants to survive for more than 50 million years.

Both lectures begin at 7:00 P.M. in the Main Auditorium. Advance admission for the two-evening series is $30 ($20 for members); for one evening, $20 ($15 for members). Tickets may be ordered from the Special Events/Development Office, American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024-5192. Call (212) 769-5166 for further information.

MIDDLE EAST MONTH

Egyptian hieroglyphics, Kurdish culture, Jewish ceremonial art, Turkish life, and songs of Lebanon are some of the topics that will be explored during Middle East Month. Middle Eastern and North African dance and music will be performed, talks on myths, art, and architecture will be given, and short films will be shown. All programs last thirty minutes and are repeated several times each Saturday and Sunday between 1:00 and 4:30 P.M. in the Leonhardt People Center. Admission is free. For a full schedule of events, call (212) 769-5181.

TIBETAN NEW YEAR

Ceremonies and social customs related to the observance of the New Year in Tibet will be discussed on Thursday, March

Israel's Parparim dance ensemble will perform during Middle East Month.
Ted Keenan

12, by Valrae Reynolds, curator of Asian collections at the Newark Museum. Reynolds will use archival photographs and film clips to illustrate her subject. The talk will be held in the Kaufmann Theater at 7:00 P.M. Tickets are $8 ($5 for members). Call (212) 769-5606 for ticket availability.

Blueprint for Space

Guest speakers, including three-time Shuttle astronaut Charles Walker, Buzz Aldrin, the second man to set foot on the moon, and Harvard-Smithsonian astronomer Fred Whipple, will offer thoughts and observations on humankind's past and future in outer space. The audience will be encouraged, in a "town hall meeting" format, to present their views on tomorrow's voyages of discovery in space. This panel discussion, part of the "Frontiers in Astronomy and Astrophysics" series, will take place on Monday, March 23, at 7:30 P.M. in the Planetarium's Sky Theater. Tickets are $6 ($5 for members). For information about ticket availability and other scheduled happenings, call (212) 769-5900.

Joey's Adventure

A colorful cast of hand puppets will take children between the ages of five and twelve on an imaginary trip back in time to the age of mammals. Along the way, a young boy named Joey and his friend Lawrence the Lion encounter prehistoric humans and Pleistocene animals created by puppeteer Rick Lyon, a veteran performer with Jim Henson's Muppets. The program will take place on Saturday, March 7, at 11:30 A.M. and 1:30 P.M. in the Kaufmann Theater. Call (212) 769-5606 for ticket availability.

These events are held at the American Museum of Natural History, located on Central Park West at 79th Street in New York City. The Kaufmann Theater and the Leonhardt People Center are located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

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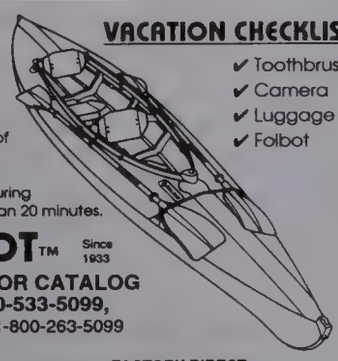

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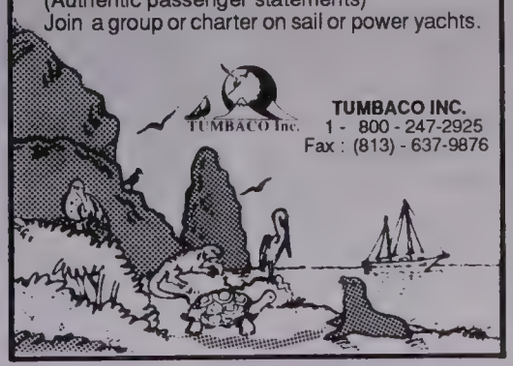

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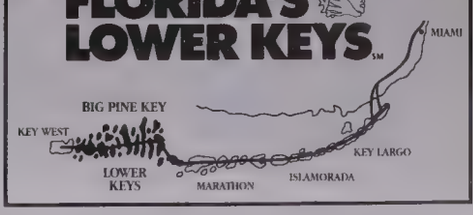

Some Like It Tart

Most cuisines temper vinegar with a sweetener, but Filipino cooks like sourness unadulterated

by Raymond Sokolov

The study of food will always be more than the sum of documents in archives and libraries, just as the study of music involves more than musicology. To study food, one must not only read about it; one must taste it in the places where it is normally eaten. Especially given the threadbare state of our knowledge about food even in our own society, it is essential that people whose expertise is eating itself should apply their palates, as well as their intelligence, to the most crucial and universal of all human activities besides sex.

Let me give an example of how an educated guess based on educated dining-out can lead to a significant advance in food history.

All accounts of the food of the Philippines agree that the national dish is *adobo,*

Adobo
René Ner

chicken marinated in vinegar and soy sauce, then cooked. This agreeable dish was always cited as an example of the allegedly overwhelming Spanish influence on the food of an Asian country ruled by Spain for centuries. Even as recently as ten years ago, visitors to the Philippines did not dispute this because the food they ate in restaurants and in the homes of the affluent people they were likely to meet was either obviously derived from Spanish models or had Spanish names. *Adobo* was the shining example. It was omnipresent, it had a Spanish name (a word signifying a marinated dish), and its ingredients looked like European ingredients with an exotic Asian salt substitute: soy sauce.

By the time I got to the Philippines in the late 1980s, Manila was teeming with aggressively "native" Filipino restaurants. Spanish was a foreign language to most citizens (having been dropped from school curricula after the Spanish-American War), and a nationwide revival of indigenous crafts called Filipiniana and of the public use of native Asian languages was in full swing. In such an atmosphere, it was natural, especially for an outsider relatively unencumbered with orthodox thinking about the Philippines—and knowledgeable enough to identify the food served in the new demotic restaurants as blatantly non-Iberian—to imagine that the Spanish influence on eating had been as superficial as it had been on so many other aspects of local civilization.

The distinguished Manila food historian Doreen G. Fernandez confirmed this attitude in its basic outlines, and she had even questioned the star role usually given to *adobo,* asserting that a sour broth called *sinigang* was much more basic—it is ubiquitous and also typical of a cuisine so preoccupied with sourness.

It was a small step, in reasoning, from there to debunking the Spanish influence that even Fernandez had assumed for *adobo.* On my return, I wrote in this magazine that *adobo* was Spanish in name only. All its ingredients were present in pre-Hispanic Manila: vinegar marination (in many vinegars prepared from rice, nipa palm, and other indigenous sources) was *the* local cooking method, and it made excellent sense to speculate that the name *adobo* had been applied by the Spanish, as so often in other cases, to a preexisting local dish.

Fernandez looked into the matter and found an early reference to *adobo* in a dictionary of Tagalog (*Vocabularios de la Lengua Tagala*) compiled by Pedro de San Buenaventura in 1613. In his definition of *cqilao,* his spelling for the word *kilaw* (rapid, heatless cooking in vinegar or other sour mediums), San Buenaventura called it the *adobo* of the natives (*adobo de los naturales*). So there we have an early document by a Spanish scholar of local language and customs, in which the word *adobo* is applied as a Spanish gloss for indigenous vinegar marination. Q.E.D.

Some historians would probably dismiss this discovery as the resolution of a moderately interesting quibble among foodies, not as weighty as what economic history could do with the history of sugar in the New World. Compared with that engine of slavery, colonization, and nutritional decadence, the whole subject of food as food is, for them, a nonstarter. Myself, I think that people with tenure are privileged to rehash well-known themes like the sugar/slave/rum connection, but that the taxonomy and etymology of the world's cuisines make up a rich, largely unexplored field of great importance.

To put *adobo* in its proper place, as one of many vinegar-soaked native dishes,

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crystallizes an original, even a radical view of Philippine history. A truly Filipino *adobo* is startling proof of the resilient survival of indigenous culture in a European colony that lasted almost four centuries. Like the disappearance of the Spanish language, the survival of Filipino food is a strong argument against the cliché that local culture always succumbs to that of the colonizer. And from the gastro-ethnographic point of view, firmly placing *adobo* in a grid of Filipino vinegar dishes makes a study of that subject much richer than it might have been (I'm thinking of *Kinilaw: A Philippine Cuisine of Freshness,* by Fernandez and Edilberto N. Alegre, Bookmark, 1991). And if you will forgive yet another series of speculations, I want to discuss vinegar in general for a moment.

In the European experience, vinegar is an acidic byproduct of wine (in French *vinaigre,* from *vin aigre,* means "sour wine"). In our day, most vinegar is produced deliberately, with an introduced bacterial colony, called the mother, that converts wine (or cider or beer) to a dilute form of acetic acid. (Mothers are divided and shared; I once heard of a bride receiving a piece of Craig Claiborne's mother as a wedding present.)

It seems certain that this process was discovered on many occasions and in many places by accident when leftover wine "spoiled" and turned into something pleasant but very different. Vinegar dates to biblical times in Western culture, when it was taken for refreshment (Ruth 2:14).

I have met people who acquired the habit of drinking vinegar as children, perhaps in unconscious imitation of Christ on the cross, who in one of the Gospels receives vinegar from a sponge lifted up to him on a lance by one of the soldiers. In general, however, we do not consume vinegar alone and rarely even as an overt, unmasked major ingredient of a dish.

The Filipino craving for unadulterated vinegar and other sour ingredients is unusual. The rule elsewhere is for vinegar to be matched with or diluted by some other ingredient. In Szechwan, they cut the hotness of chili oil as a condiment for dumplings by stirring in rice vinegar. France has *sauce aigre-douce,* in which sugar and white wine match vinegar.

Italian *agrodolce* comes to much the same thing. And in one Italian preparation of sweet-and-sour lamb, the meat is first marinated in seasoned vinegar to which sugar is later added to make a sauce.

The most famous balancing act in Western cookery is, of course, vinaigrette, in which oil cuts the vinegar. This principle is also the active one in a great many marinades for meat, poultry, and fish, not to mention barbecue sauces, in which the presence of hot pepper and tomato disguises the fundamental nature of the medium.

Clever cooks continue to expand on this basic idea of matching. Anna Del Conte, in *The Italian Pantry* (Harper and Row, 1990), suggests adding very powerful balsamic vinegar to the creamy cheese called *mascarpone* and then balancing out the flavors with a little sugar.

It may well be that all these marinades and dressings and other tamings of vinegar go back to a primordial use of vinegar as a pickling or preserving agent. Chemically speaking, the acid acts as a bactericide or, in the case of brine-fermented pickling (dill pickles), as a bacterial filter that favors only flora that prosper at a specific acidity and provide a welcome taste.

Pickling mixtures, with their complicated combinations of spices and flavorings, would have been concocted so as to make the resulting pickles palatable, that is, to mask the ferocity of the vinegar. This way of handling acidity can be seen

Escabeche de Alcachofas
(Artichoke Escabeche)

Rojas-Lombardi wrote: "Certain vegetables are fabulous when prepared in an escabeche, especially those rich in natural sweetness, such as artichokes. The sweetness contrasts with the tartness of the vinegar, creating a well-balanced and aromatic dish."

8 medium artichokes (about 8 ounces each) or 16 baby artichokes (about 2 ounces each)
1 lemon
2 tablespoons coarse salt
1 cup olive oil
4 cloves garlic, peeled
2 medium onions, peeled and sliced into ¼-inch rings
2 large carrots, peeled and cut into sticks, 3 by ⅛ inch
1 serrano or jalapeño pepper, seeded and julienned
1 bay leaf
12 black peppercorns
6–8 sprigs fresh oregano, chopped, or ½ teaspoon dried oregano
⅛ teaspoon ground nutmeg
½ cup red-wine vinegar
1½ cups white wine
Sprigs of fresh oregano

1. Wash the artichokes in cold water. Fill a bowl large enough to hold all the artichokes with about 2 quarts of cold water. Juice half the lemon and pour into the bowl. With a large knife cut off the stem flush with the base of each artichoke. Pull off and discard any small or discolored leaves around the base. Remove one or two rows by bending each leaf outward and down so that the top part snaps off the leaf's fleshy base. Place the artichoke on its side on a cutting board, and with a sharp knife, cut about 1 to 1½ inches off the top. With kitchen scissors, trim off the thorny tips of the remaining leaves. As each artichoke is trimmed, drop it immediately into the water with the lemon juice to prevent discoloration. Keep the artichokes there until ready to cook.
2. In a large enamel or stainless steel pot, bring 4 quarts of water, 1 tablespoon of salt, and the juice of the remaining half lemon to a boil. Drop the artichokes into the boiling water and cook them for about 15 to 20 minutes, or until they are barely tender. Remove the artichokes from the water and turn them upside down in a colander or on a rack to drain.
3. In an earthenware casserole, heat the olive oil. Add the garlic and sauté over medium heat for just 1 or 2 seconds. Do not let the garlic brown or burn. Add the onions, carrots, pepper, bay leaf, peppercorns, chopped oregano, nutmeg, and the remaining tablespoon of salt. Sauté for 2 minutes. Add the artichokes, cook for 1 minute, and pour in the vinegar and white wine. Stir and bring to a boil. Lower the heat and simmer for 5 minutes. Remove from heat and set aside to cool to room temperature. Serve right from the casserole, garnished with the oregano sprigs.

Yield: 8 servings

Note: Artichokes can also be cut lengthwise into halves or quarters, especially if they are very large. Do this after trimming them. Then, using a paring knife or teaspoon, cut off or scoop out the fuzzy chokes, discard them, and proceed with the recipe.

You may also substitute 2 or 3 heads of broccoli or cauliflower for the artichokes. Separate the heads into florets, blanch, and drain. Proceed with the recipe from step 3 on. Or substitute 5 pounds of okra for the artichokes. Trim the stems without cutting the pods, then blanch in salted water and drain. Proceed with the recipe from step 3 on.

Escabeches made with these vegetables, alone or in combination, all keep well, tightly covered, for up to 10 days in the refrigerator.

in its most complex and widespread form in *escabeche,* a method of food preservation brought to Spain by the Moors and then spread to the Americas—to Jamaica, where it appears as an *escoveitch* fish, and to the former Spanish colonies, where the late Felipe Rojas-Lombardi, a Peruvian, encountered it as a major division of everyday cookery.

As Rojas-Lombardi expresses in *The Art of South American Cooking* (HarperCollins, 1991):

Making an escabeche is quick and uncomplicated. All that is required is to cook some fresh fish, poultry, game, or vegetables, pour over just enough hot vinegar to cover the ingredients, then let the dish cool so the flavors have a chance to mingle. The acidity of the dish is usually tempered by simmering the vinegar with water, wine, stock, coconut milk or almond milk.

Rojas-Lombardi also mentions *escabeches* "mellowed" by aromatic vegetables, sweet spices, figs, dates, prunes, raisins, peanuts, cashews, and other nuts, as well as paprika, achiote, or turmeric for coloring.

Two basic features separate *escabeche* from that other acid-based method of cookery also popular in South America: seviche. Like the Filipino *kinilaw,* seviche immerses food in an untempered acid medium and the food is raw. Neither heat nor a sweet or diluting ingredient is added. Together, seviche and *escabeche* represent opposite poles of vinegar (or acid) cookery. Seviche is the epitome of laissez faire: The acid medium is left alone and the food to be "cooked" is left alone in it, unassaulted by adventitious heat.

Escabeche is a cuisine of intervention. The vinegar is muffled and costumed, enhanced and subdued. The food is thoroughly cooked before it ever encounters the equally well-heated vinegar.

Different as they are, seviche and *escabeche* take us back to the origins of civilized eating, to an era before refrigeration, when the risk of rot inspired cooks to save spoiled wine and use it in turn to save or improve other foods. The ideas were simple and their discovery went unrecorded. Today, they represent the limits of cooking, from the least to the most active. Both methods have been preserved into the age of refrigeration, after outliving their original raison d'etre, because they are outstanding routes to the delicious—and perhaps because, unconsciously, people sense that they reflect two fundamental approaches to life, the passive and the active.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

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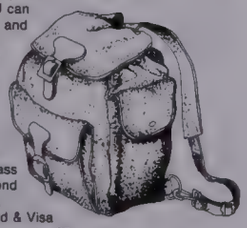

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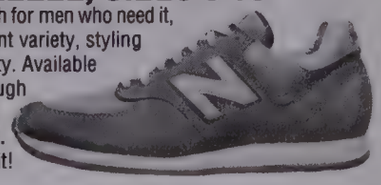

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Three times saltier than the sea, California's Mono Lake, east of the Sierra Nevada, is devoid of fish but harbors millions of brine fly larvae. Two or three generations of brine flies hatch out each year and take to the beach in hordes of up to 4,000 flies per square foot, blackening parts of the alkaline shoreline. Innocuous to humans, the insects share the lake with migrating birds, such as grebes and phalaropes, as well as nesting snowy plovers and California gulls. In some years, 25,000 pairs of California gulls, about 20 percent of the breeding population, raise their young at Mono Lake. The water level of this avian stopover and breeding spot has dropped forty-five feet since the diversion of freshwater feeder streams began fifty years ago. While brine flies may enjoy the water's salinity, only an influx of fresh water prevents the lake, its islands, and its shores from growing too tangy to sustain the traditionally rich birdlife.

For a salty snack, a California gull merely has to stroll along the "fly zone" on the beach with its mouth agape, a fairly efficient way for it to feed, given the insect density. (The gulls' appetite for insects won them the lasting gratitude of a group of Mormons in Utah when, in 1848, the birds rescued a new settlement by devouring swarms of crop-ravaging grasshoppers.) According to the photographer, who remained tight-lipped while setting up his equipment, this bird didn't pluck individual flies from the air, but instead treated them "as an aggregation, as a gas, so to speak, rather than as molecules."—*J. R.*

Photograph by
Arthur M. Greene

In 1965, after beginning undergraduate training in architecture at Harvard, **Nicholas M. Hellmuth** (page 18) spent a year with archeologists excavating the Maya site of Tikal. There he observed the architectural influence of the central Mexican city of Teotihuacán, an example of the cultural interchange between the two regions that has intrigued him ever since. As director of the Foundation for Latin American Anthropological Research, he has documented Teotihuacán-style artifacts discovered in Guatemala's southern department of Esquintla and mapped Yaxhá in the northern department of Petén. His current efforts include researching the iconography of Maya ballgames, building a photo archive of sites in the northwest Yucatán Peninsula, using computer programs to do reconstruction drawings of Maya architecture, and completing his photo archive of all Maya vases in museums and accessible private collections worldwide. Hellmuth, who received a doctorate in art history from the University of Graz, Austria, is a curatorial affiliate of Yale's Peabody Museum of Natural History, as well as a visiting professor of art at Rollins College, Winter Park, Florida. For additional reading he recommends *The Maya,* by Michael D. Coe (New York: Thames and Hudson, 1987), and *The Art of Mesoamerica,* by Mary Miller (London and New York: Thames and Hudson, 1986).

A biologist and conservationist with the National Fisheries Service, **Scott A. Eckert** (page 28) is coordinator of its Pacific Sea Turtle Recovery Team and, with his wife, Karen, coeditor of the *Marine Turtle Newsletter,* which tracks the status of the world's endangered sea turtle populations. In 1980, the Eckerts, above, were initiated into sea turtle research by James I. Richardson, director of the Marine Turtle Research Program at the University of Georgia. "After spending a summer working with him on a loggerhead turtle nesting beach on the Georgia coast," Eckert writes, "a whole new world opened up to us. We've taken what we learned that summer and expanded it into fieldwork from Mexico to Malaysia." In addition to using electronic recorders to track the dives and movements of leatherbacks in the Virgin Islands and the South China Sea, Eckert has helped survey sea turtle nesting sites in Guyana and investigated emperor penguins and Weddell seals in Antarctica. For more on sea turtles, he recommends *Diverse Divers,* by G. L. Kooyman (Berlin: Springer-Verlag, 1989), and *The Turtles of Venezuela,* by P. C. H. Pritchard and P. Trebbau (Caracas: Society for the Study of Amphibians and Reptiles, 1984).

Katharine Milton (page 36) first traveled to Brazil in 1979 to expand her studies of howler monkeys, which she began five years earlier in Panama. She soon decided that a critical area deserving immediate research was the behavior of the little-contacted indigenous human groups that remained in the threatened forest environment. She has especially

sought to document traditional subsistence activities and diet, but she also continues to study the ecology of howler monkeys, including their interactions with such parasites as botflies. A professor of anthropology at the University of California, Berkeley, Milton recommends the following sources for additional reading on the impact of change on Amazonian peoples: *Red Gold: The Conquest of the Brazilian Indians,* by John Hemming (Cambridge: Harvard University Press, 1978); *The Panare: Tradition and Change on the Amazonian Frontier,* by Paul Henley (New Haven: Yale University Press, 1982); and *People of the Tropical Rain Forest,* edited by Julie Sloan Denslow and Christine Padoch (Berkeley: University of California Press, 1988).

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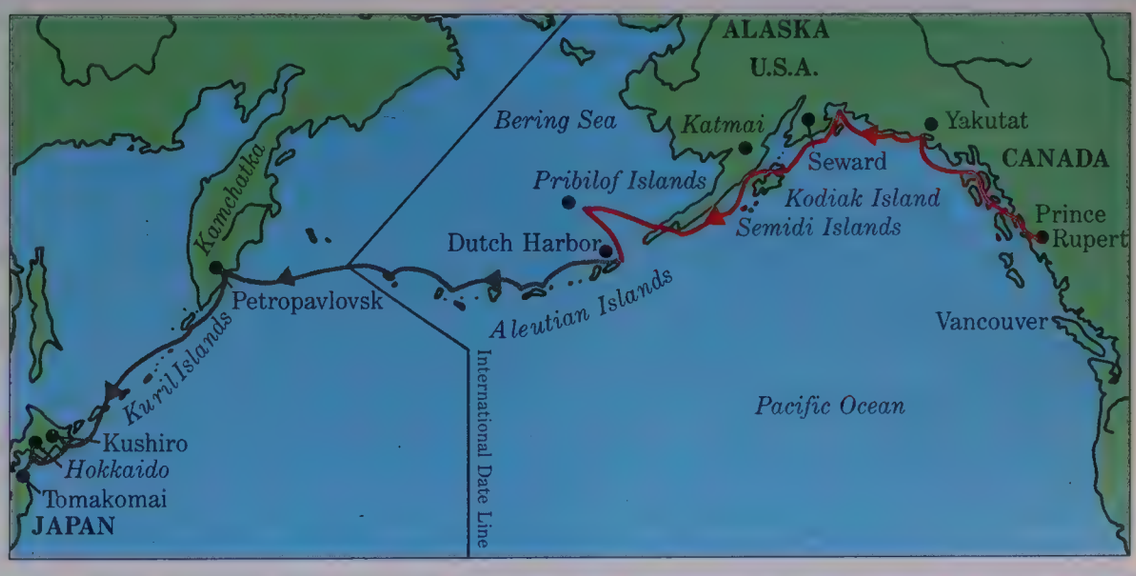

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As an undergraduate at the University of Glasgow, **George Barron** (page 46) was given some moldy moss to study in a botany laboratory. He found that the molds were much more exciting than the moss and has been studying them ever since. Barron received his Ph.D. from Iowa State University and is now a professor of environmental biology at the University of Guelph in Ontario, Canada. His recent discoveries on the Jekyll-Hyde nature of wood-decaying fungi have opened up new research possibilities, which he and a graduate student

are pursuing. Early in his career, Barron published a guide to soil fungi, but later his interest switched from their taxonomy to their ecology as he became more curious about their roles in nature. In the early seventies he began studying parasites that prey on nematode worms and has since discovered many new and unusual parasites. In 1984 Barron was awarded a doctorate of science from the University of Glasgow in recognition of his work on the biology of soil fungi. He enjoys field trips and says his photo shows him "hard at work collecting samples during a visit to New Zealand."

Some nine years ago, when he was a doctoral student at the University of Miami, **Randall Breitwisch** (page 56) became interested in how different species of animals communicate with each other. During a trip to Kenya in 1990, he had a chance to witness such communication by observing the body language of oxpeckers and mammals of the East African savanna. Now an assistant professor of biology at the University of Dayton in Dayton, Ohio, Breitwisch has previously written for *Natural History* on the varied repertoire of northern mockingbirds (June 1989). While he has studied birds and mammals in Australia, Africa, and Central and South America, his current research involves a species closer to home—the northern cardinal. Breitwisch continues to work on developing a theory of interspecific communication in animals and is also writing a book of essays on animal behavior. For more information on animal interactions, he recommends one popular account, Cynthia Moss's *Portraits in the Wild: Animal Behavior in East Africa* (Chicago: University of Chicago Press, 1982), and a more technical treatment, Robert Axelrod's *The Evolution of Cooperation* (New York: Basic Books, 1984).

A native of New York City, **Arthur M. Greene** (page 84) got his start in photography at age twelve with a Brownie camera and the darkroom at his day camp. Today, he is a studio and nature photographer, but along the way he earned a degree in engineering from Columbia University and another in music from Stanford University. Photography gives him a chance to indulge both his scientific and artistic sides. Although Greene has traveled to many scenic parts of the country—his award-winning entry in *Natural History*'s 1990 photo contest was taken in Denali National Park in Alaska—he also enjoys taking photographs closer to home. He captured the California gull feeding on brine flies, this month's "Natural Moment," with a Nikon F3 and 500mm lens, which he set up about twenty feet from the teeming Mono Lake "fly zone."

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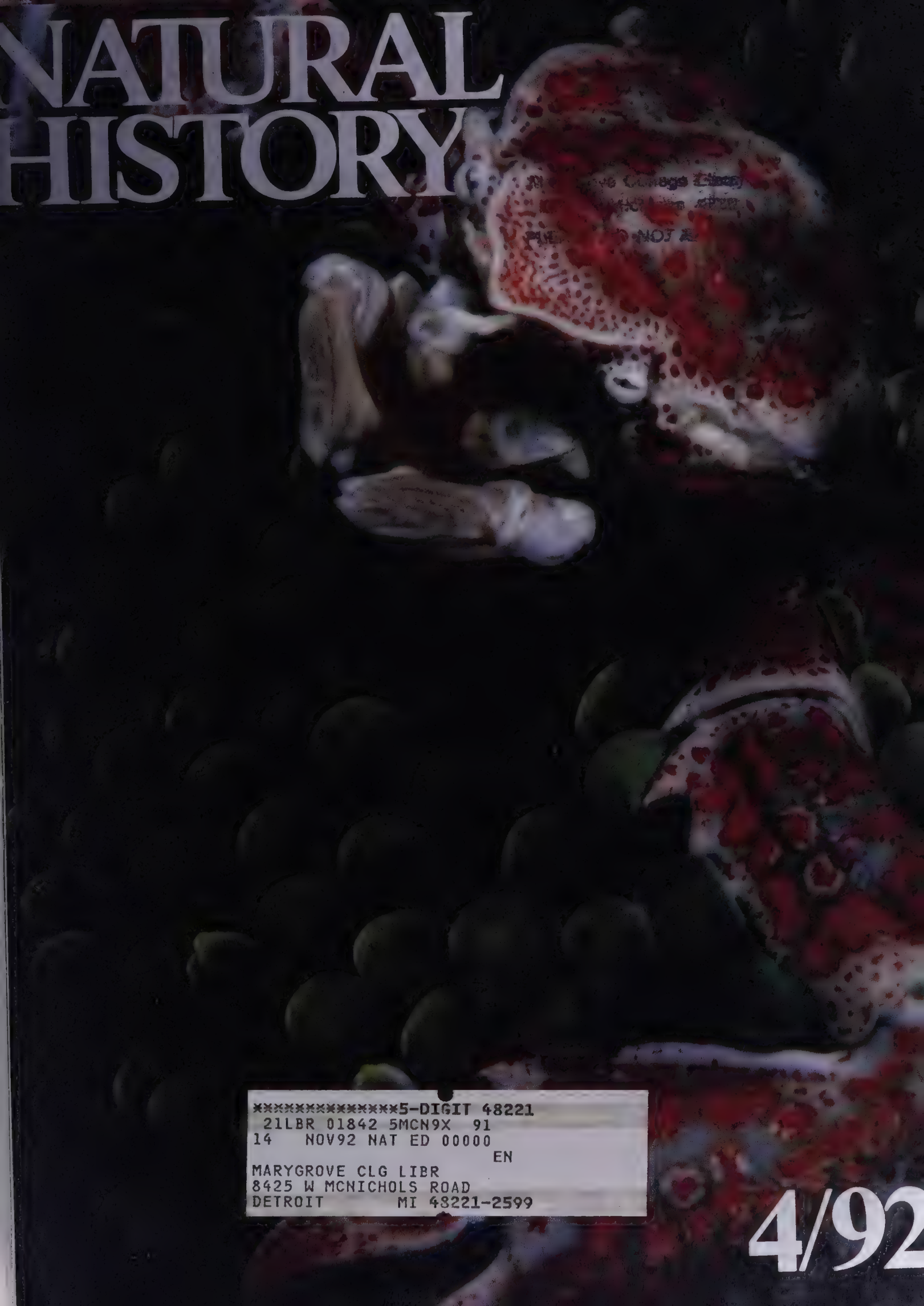

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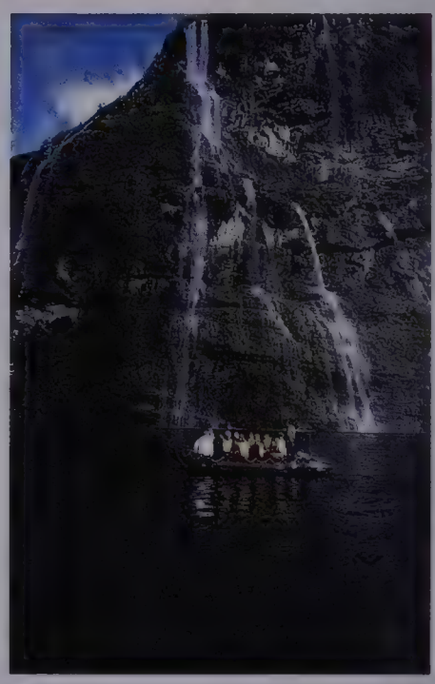

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APRIL 1992

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NATURAL HISTORY (ISSN 0028-0712) is published monthly by the American Museum of Natural History, Central Park West at 79th Street, New York, N.Y. 10024. Subscriptions: $25.00 a year. In Canada and all other countries: $34.00 a year. Second-class postage paid at New York, N.Y., and at additional mailing offices. Copyright © 1992 by American Museum of Natural History. All rights reserved. No part of this periodical may be reproduced without written consent of *Natural History*. Send subscription orders and undeliverable copies to the address below. Membership and subscription information: Write to address below or call (800) 234-5252 if urgent. POSTMASTER: Send address changes to Natural History, Post Office Box 5000, Harlan, IA 51537-5000.

HOW WARM WERE THE HUGE AND FAMOUS?

I'd like to disagree with one point in Peter Dodson's "Life Styles of the Huge and Famous" (December 1991). Dodson argues that sauropod dinosaurs could not have been warmblooded (endothermic) because being so would have put them at a "severe risk of fatal overheating." This conclusion is based on a computer model that predicts elephant-sized endotherms could not exist. The model can't explain the existence of elephants, let alone extinct ten-ton mammoths or the twenty-ton rhino *Paraceratherium,* unless all were coldblooded (ectothermic).

The idea that big endotherms overheat and die easily was disproved more than twenty years ago by C. Richard Taylor of Harvard University, who demonstrated that big mammals (over 200 pounds) use their bulk to store their body heat and permit body temperature to rise slowly over the day. As long as body temperature is higher than air temperature, internally produced heat flows outward and evaporative water loss (panting, sweating) is low, so dehydration is minimized. In desert climates, where air temperature can exceed body temperature, the size of large endotherms slows external heat gain, so that internal temperatures do not rise to critical levels. Any excess body heat is unloaded during the night. Studies by Peter Hiley and V. A. Langman indicate that elephants and rhinos use this strategy; endothermic sauropods probably did too.

Endothermy is actually advantageous to big animals in warm climates because the higher the body temperature, the higher the air temperature has to be for external heat to flow in. Ectotherms are unprotected; for them, heat flow is always inward under open skies. Giant Aldabra tortoises, for example, die in great numbers from overheating in full sun. Similarly, 1,000-pound sea turtles usually nest at night, as heat gain on a sunny day would cause severe heat stress before egg laying was complete. Sauropods lived in open habitats and would have been vulnerable to death from heat stroke if they were ectothermic.

GUY LEAHY
Eugene, Oregon

PETER DODSON REPLIES:

I agree with Mr. Leahy that elephants indeed exist! But female African elephants are only one-tenth the weight of the thirty-ton sauropod that we used in our computer calculations. Furthermore, elephants can die from heat stroke when they are sedated (for the attachment of radio transmitters) unless special care is taken to cool them; this suggests that elephant vascular systems used for cooling are indeed taxed in full sunlight.

Our models show that for a large animal, whether an endotherm or an ectotherm, getting rid of heat—not heating up—is the real problem. Since body temperature is the mean ambient temperature plus whatever is added by metabolic activity, the higher the metabolic rate, the greater the danger of overheating. The mean ambient temperature was higher in the Jurassic than today; correspondingly, the safe metabolic increment was smaller.

Dumping heat at night is a useful strategy for temperature regulation, provided nights are long enough and cool enough and that anatomical structures can do the job. Contact with water or moist soil is an excellent strategy for heat loss, but we prefer to think that sauropods were not dependent upon water. We also do not believe that sauropods' necks and tails were particularly effective heat-exchange structures.

The point of our model is not that very large mammals cannot exist, but that they are critically dependent on efficient heat exchange. Very large dinosaurs certainly enjoyed the benefits of warm and constant body temperatures, but they did so at a low metabolic rate. Natural selection would operate against unnecessary metabolic costs and thermoregulatory risks of an elevated metabolic rate.

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Global Warming on Trial

How good is the evidence that the earth is warming, and where does the burden of proof lie?

by Wallace S. Broecker

Jim Hansen, a climatologist at NASA's Goddard Space Institute, is convinced that the earth's temperature is rising and places the blame on the buildup of greenhouse gases in the atmosphere. Unconvinced, John Sununu, former White House chief of staff, doubts that the warming will be great enough to produce a serious threat and fears that measures to reduce the emissions would throw a wrench into the gears that drive the United States' troubled economy. During his three years at the White House, Sununu's view prevailed, and although his role in the debate has diminished, others continue to cast doubt on the reality of global warming. A new lobbying group called the Climate Council has been created to do just this.

The stakes in this debate are extremely high, for it pits society's short-term well-being against the future of all the planet's inhabitants. Our past transgressions have altered major portions of the earth's surface, but the effects have been limited. Now we can foresee the possibility that to satisfy the energy needs of an expanding human population, we will rapidly change the climate of the entire planet, with consequences for even the most remote and unspoiled regions of the globe.

The notion that certain gases could warm the planet is not new. In 1896 Svante Arrhenius, a Swedish chemist, resolved the longstanding question of how the earth's atmosphere could maintain the planet's relatively warm temperature when the oxygen and nitrogen that make up 99 percent of the atmosphere do not absorb any of the heat escaping as infrared radiation from the earth's surface into space. He discovered that even the small amounts of carbon dioxide in the atmosphere could absorb large amounts of heat. Furthermore, he reasoned that the burning of coal, oil, and natural gas could eventually release enough carbon dioxide to warm the earth.

Hansen and most other climatologists agree that enough greenhouse gases have accumulated in the atmosphere to make Arrhenius's prediction come true. Burning fossil fuels is not the only problem; a fifth of our emissions of carbon dioxide now come from clearing and burning forests. Scientists are also tracking a host of other greenhouse gases that emanate from a variety of human activities; the warming effect of methane, chlorofluorocarbons, and nitrous oxide combined equals that of carbon dioxide. Although the current warming from these gases may be difficult to detect against the background noise of natural climate variation, most climatologists are certain that as the gases continue to accumulate, increases in the earth's temperature will become evident even to skeptics.

A special exhibition, **Global Warming—Understanding the Forecast**, will première at the American Museum of Natural History on May 15 and run through January 3, 1993. The exhibit, jointly produced by the Museum and the Environmental Defense Fund, will then travel to Los Angeles, Washington, D.C., and other cities.

The issue under debate has implications for our political and social behavior. It raises the question of whether we should renew efforts to curb population growth and reliance on fossil fuels. In other words, should the age of exponential growth initiated by the Industrial Revolution be brought to a close?

The battle lines for this particular skirmish are surprisingly well balanced. Those with concerns about global warming point to the recent report from the United Nation's Intergovernmental Plan on Climate Change, which suggests that with "business as usual," emissions of carbon dioxide by the year 2025 will be 25 percent greater than previously estimated. On the other side, the George C. Marshall Institute, a conservative think tank, published a report warning that without greenhouse gases to warm things up, the world would become cool in the next century. Stephen Schneider, a leading computer modeler of future climate change, accused Sununu of "brandishing the [Marshall] report as if he were holding a crucifix to repel a vampire."

If the reality of global warming were put on trial, each side would have trouble making its case. Jim Hansen's side could not prove beyond a reasonable doubt that carbon dioxide and the other greenhouse gases have warmed the planet. But neither could John Sununu's side prove beyond a reasonable doubt that the warming expected from greenhouse gases has not occurred.

To see why each side would have difficulty proving its case, let us review the arguments that might be presented at such a hearing. The primary evidence would be the temperature records that have been kept by meteorologists since the 1850s. A number of independent analyses of these measurements have reached the same basic conclusions. Over the last century the planet has warmed about one degree. This warming was especially pronounced during the last decade, which had eight of the warmest years on record, with 1990 being the hottest. While Sununu's group might question the adequacy of the geographic coverage of weather stations during the early part of the record and bicker a bit about whether the local warming produced by the growth of cities has biased some of the records, in the end they would concede that this record provides a reasonably good picture of the trend in the earth's temperature. Sununu's advocate would then counter by asking, "Isn't it strange that between about 1940 and 1975 no warming occurred?" The Hansen group would have to admit that there is no widely accepted explanation for this leveling. Sununu's advocate would continue,"Isn't it true that roughly half the warming occurred before 1940, even though almost all the emissions of carbon dioxide and other greenhouse gases have taken place after this date?" Again the Hansen group would have to admit this to be the case.

At this point, a wise judge might pose the following question to both sides: "What do we know about the temperature

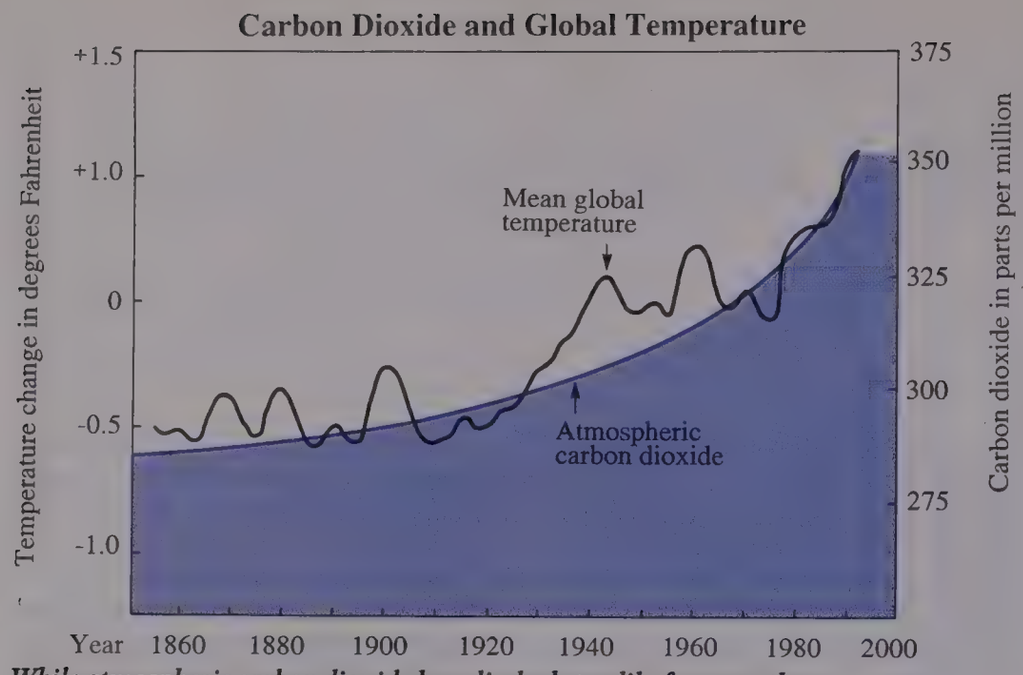
fluctuations that occurred prior to the Industrial Revolution?" The aim of this question would be to determine what course the earth's temperature might have taken if the atmosphere had not been polluted with greenhouse gases. The answer by both sides would have to be that instead of remaining the same as it was in 1850, the planet's temperature would have undergone natural fluctuations, which could have been as large as the changes measured over the last one hundred years. Neither side, however, would be able to supply the judge with an acceptable estimate of what would have happened to the earth's temperature without the release of greenhouse gases.

Perhaps a longer record of the earth's climate would shed light on its natural variability. The climate prior to 1850 can be reconstructed from historical records of changing ice cover on mountaintops and on the sea. The earliest evidence of this type dates from the end of the tenth century A.D., when Eric the Red first sailed from Iceland to Greenland. Ship logs written between that time and 1190 indicate that sea ice was rarely seen along the Viking sailing routes. The temperature was warm enough that grain could be grown in Iceland. At the end of the twelfth century, however, conditions deteriorated, and sea ice appeared along the Viking sailing routes during the winters. By the midfourteenth century, these routes were forced far to the south because of the ice, and sometime in the late fifteenth century, ships were cut off altogether from Greenland and Iceland because of severe ice conditions. As temperatures dropped, people could no longer grow grain in Iceland. The Medieval Warm had given way to the Little Ice Age.

After 1600, records of sea-ice coverage around Iceland and of the extent of mountain glaciers in the Alps improved, giving us an even better idea of recent climate change. The glaciers attracted the attention of seventeenth-century tourists, including artists whose drawings and paintings document the position of a number of

Hunters in the Snow *was painted by Pieter Bruegel the Elder in the winter of 1564–65, one of the most severe of the Little Ice Age.*

Courtesy of the Kunsthistorisches Museum, Vienna



While atmospheric carbon dioxide has climbed steadily for more than a century, the earth's temperature shows a more erratic upward trend.

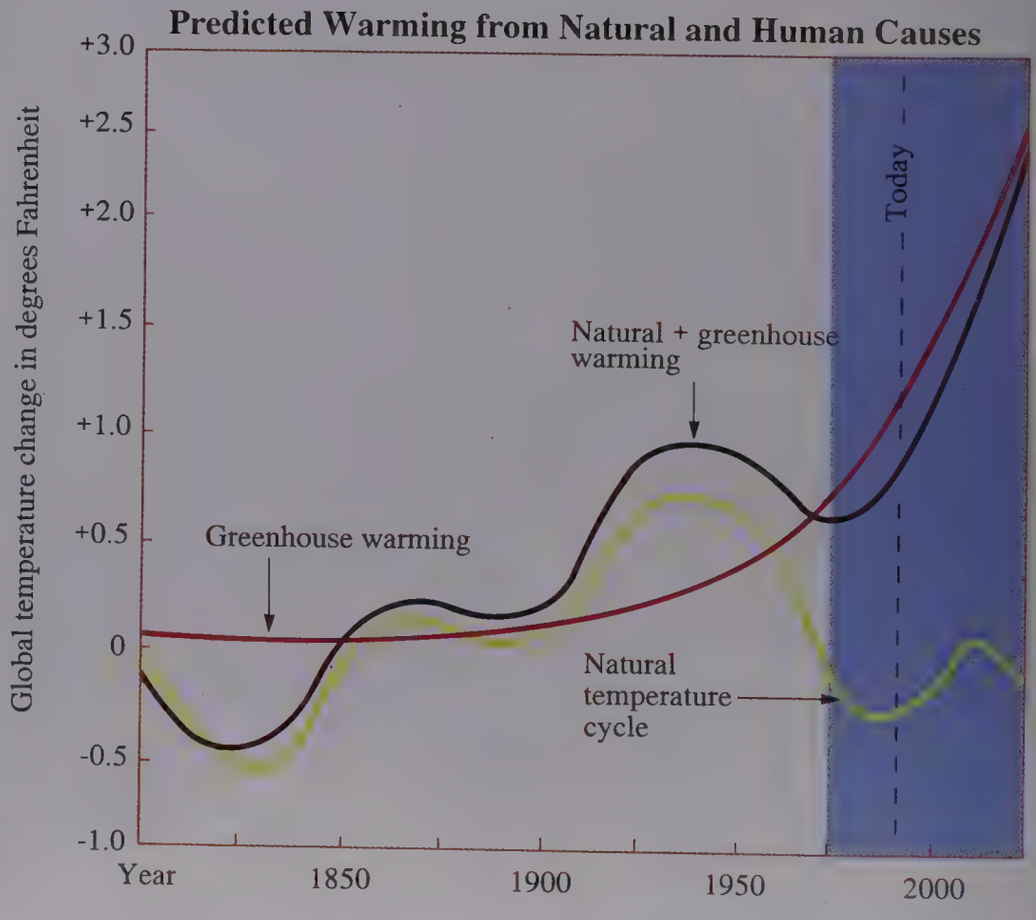
major Alpine glaciers. Modern measurements show that the leading edges of these glaciers fluctuated with temperature changes over the last century. Assuming that this correlation held true throughout the Little Ice Age, the historical evidence shows a long interval of glacier expansion, and thus cold climate, lasting until 1860. During the late 1800s, a widespread recession of Alpine glaciers heralded the end of the Little Ice Age. Ridges of rock and earth bulldozed into position by the advancing ice still mark the point of maximum glacial progress into the valleys. (The glaciers are still shrinking; less than half of their 1860 volume remains.) The mild conditions that prevailed during the Medieval Warm did not return until this century.

The problem with all this evidence is that it represents only one region of the earth and is, in a sense, anecdotal. An informed judge might also challenge this evidence by pointing out that the northern Atlantic Ocean and its surrounding lands are warmed by powerful ocean currents, collectively known as the Great Conveyor, that transport heat away from the equator (*see* "The Biggest Chill," *Natural History,* October 1987). A temporary shutdown of this circulation 11,000 years ago brought about an 800-year cold period called the Younger Dryas, during which northern Europe was chilled by a whopping 12° F. Could the Little Ice Age have been brought about by a similar weakening of the Great Conveyor? If heat release from the northern Atlantic was the key factor, the Little Ice Age would have been restricted to the surrounding region, and the historical evidence from Iceland and the Alps could not be taken as an index of global temperatures.

Although records of similar duration and quality are not available from other parts of the world, we do have firm evidence that by 1850, mountain glaciers in some regions, such as New Zealand and the Andes, reached down into valleys as far as they had at any time during the last 8,000 years. Furthermore, by 1870 these glaciers had also begun their retreat. This suggests that the Little Ice Age was indeed global in extent.

The global warming that caused the demise of the Little Ice Age confuses attempts to estimate how much of the last century's warming is natural and how much has been caused by pumping greenhouse gases into the atmosphere. The Sununu side would pin as much of the blame as possible on the natural warming trend that ended the Little Ice Age, while Hansen's side would emphasize the role of the greenhouse gases. What is needed to resolve this dispute is a detailed, continuous temperature record that extends back beyond the Medieval Warm to see if cycles could be identified. By extending these cycles into the present century, scientists could estimate the course the earth's temperature would have taken in the absence of the Industrial Revolution.

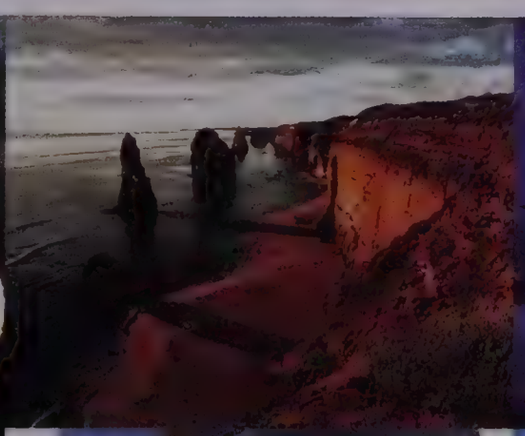
I made such an attempt in 1975, at a time when the earth's temperature seemed to have remained almost constant since the mid-1940s. Puzzled scientists



In 1975, the author published this diagram, suggesting that despite a rise in greenhouse gases, the earth cooled somewhat during the 1960s and 1970s because it was at the low point of a natural temperature cycle. He predicted the warming of the 1980s, when the natural cycle again turned upward, no longer masking the effect of the gases.

Graphs by Joe LeMonnier

Fair Dinkum* Australia.



***fair dinkum/** —*Colloq.* —*adj.* 1: true, genuine, dinkum ‹are you fair dinkum?› —*interj.* 2: assertion of truth or genuineness ‹it's true, mate, fair dinkum› 3: Come have a fair dinkum great time in Australia.

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were asking, "Where's the expected greenhouse warming?" I looked for the answer in the only detailed long-term record then available, which came from a deep hole bored into northern Greenland's icecap at a place called Camp Century. In the 1950s, Willi Dansgaard, a Danish geochemist, had demonstrated that the ratio of heavy to light oxygen isotopes (18 neutrons to 16 neutrons per atom, respectively) in the snow falling in polar regions reflected the air temperature. Dansgaard made measurements of oxygen isotopes in different layers of the ice core; each represented the compressed snowfall of an arctic year. His results served as a proxy for the changes in the mean annual temperature. Dansgaard and his colleagues analyzed the record to see if the temperature fluctuations were cyclic. They found indications of two cycles, one operating on an 80-year time scale and a weaker one operating on a 180-year time scale. (The Milankovitch cycles, caused by changes in the earth's orbit around the sun, operate on a much longer time scale. Ranging from 20,000 years upward, these cycles are thought to control the large swings between glacial and interglacial climates.)

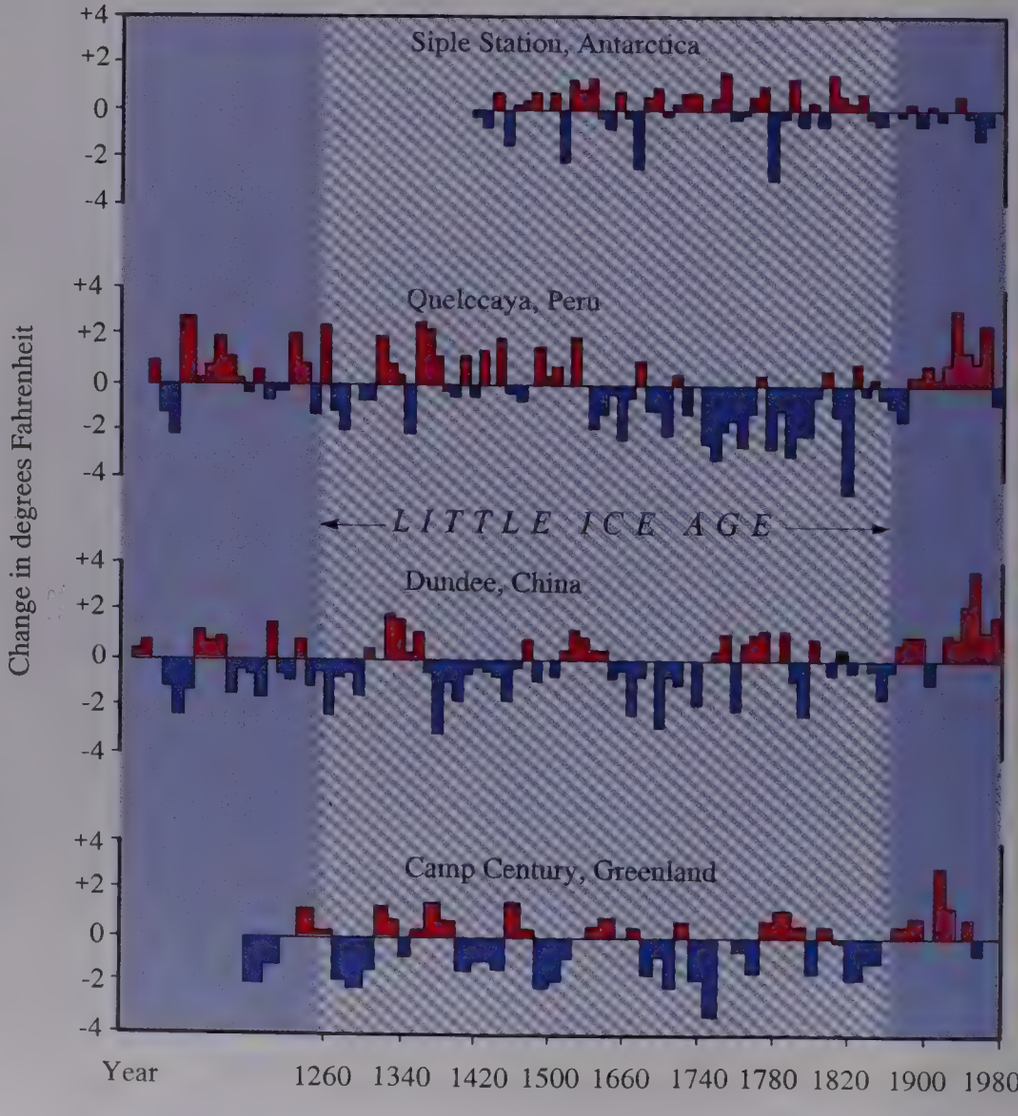
I took Dansgaard's analysis a step further by extending his cyclic pattern into the future. When combined with the expected greenhouse warming, a most interesting result appeared. Temperatures leveled off during the 1940s and 1950s and dropped somewhat during the 1960s and 1970s. Then, in the 1980s, they began to rise sharply. If there is a natural eighty-year cycle and it was acting in conjunction with a greenhouse effect, I would explain the leveling of temperature after 1940 as follows: Dansgaard's eighty-year cycle would have produced a natural warming between 1895 and 1935 and a natural cooling from 1935 to 1975. The cooling in the second half of the cycle might have counterbalanced the fledgling greenhouse warming. After 1975, when the natural cycle turned once again, its warming effect would have been augmented by the ever stronger greenhouse phenomenon, producing a sharp upturn in temperature in the 1980s.

My exercise showed that the lack of warming between 1940 and 1975 could not be used to discount the possibility that the pollution we are pumping into the atmosphere will ultimately warm the globe. We cannot rule out this possibility until that time in the future when the predicted warming is so great that it can no longer be masked by natural temperature fluctuations. My projection suggested that a firm answer will not be available until the first decade of the next century.

While the Camp Century record seemed to provide a good method of determining how natural variations and increasing greenhouse gases were working in concert to produce the measured global temperatures, additional ice core data only created confusion. Oxygen isotope records from ice cores extracted from the Antarctica icecap and mountain glaciers in China and Peru do not follow the Camp Century ice core pattern. Even worse, oxygen isotope records from three additional Greenland ice cores differ significantly from one another and from the original Camp Century record. Perhaps the most disconcerting feature of these ice core records is that the Medieval Warm and Little Ice Age do not even stand out as major features. Local temperature variations could account for these discrepancies, but oxygen isotope ratios also depend on the season the snow falls and the source of the moisture. For these reasons, ice cores may provide good records of large changes, but the smaller ones we are looking for over the last several hundred year are obscured.

At this point, the judge would likely los his patience and call a halt to this line o argument, saying, "While regional cli mate changes certainly occurred durin the centuries preceding the Industria Revolution, firm evidence for a coheren global pattern in these natural fluctua tions is lacking." The judge might the suggest a different approach to settle th question of whether we are causing th earth to warm. What drives the natura changes? If we could pin down the villain then perhaps we could say more abou how temperature would have changed i the absence of the Industrial Revolution Witnesses would point to three such mechanisms. First, the sun's energy out put may have changed. Second, large vol canic eruptions may have injected enough material into the stratosphere to reflect a substantial amount of solar radiation back into space, cooling the planet. Third, the operation of the ocean-atmosphere system

Temperature Shifts Recorded by Oxygen Isotopes in Ice Cores



Ice cores from various glaciers around the world show little agreement on past temperature shifts, reflecting local conditions that complicate the global record.

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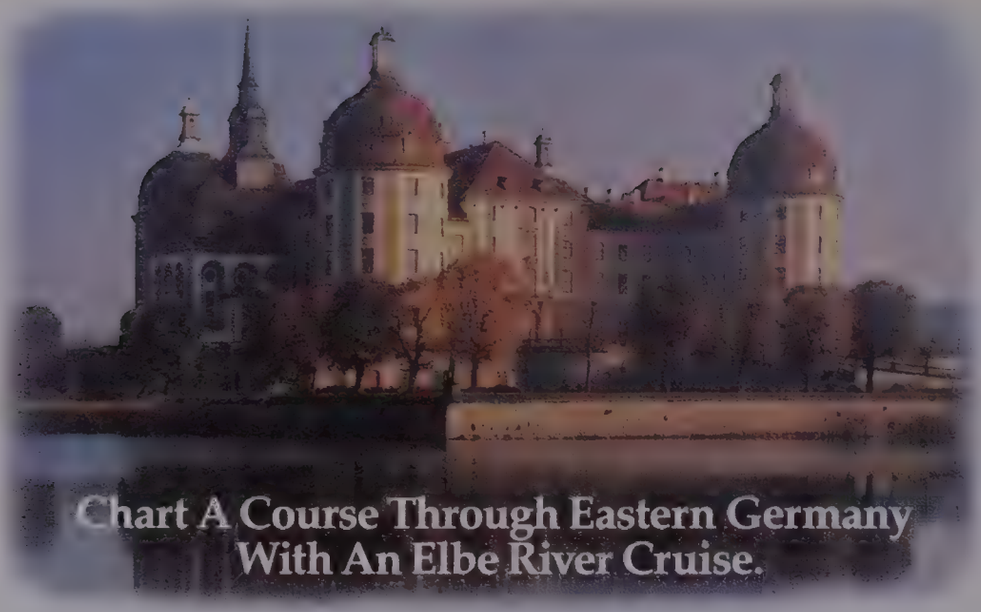

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may have changed internally, causing the earth's temperature to wander.

For several centuries astronomers have been observing the cycles of the sun and trying to link them with climate patterns on earth. Sunspots, caused by knots in the sun's magnetic field, undergo cyclic change, alternating between a maximum of spots in the Northern Hemisphere and then a maximum in the Southern Hemisphere. Between these peaks, the number of sunspots drops almost to zero. A complete solar cycle takes twenty-two years. With satellites, astronomers have been able to directly monitor the sun's energy output over the last cycles. Although the energy seems to dip slightly when sunspots disappear, the change seems too small to greatly alter the earth's temperature.

An intriguing proposal was recently made in this regard. Two Danish meteorologists, Eigil Friss-Christensen and Knud Lassen, point out that over the last 130 years for which observations are available, the sunspot cycle has lengthened and shortened with a periodicity of about 80 years, and that these changes closely parallel the earth's temperature. The Danes suggest that during intervals when the sunspot cycle is longer than average, the sun's energy output is a bit lower, and that when the cycle is shorter, the energy output is higher. Could it be that Dansgaard was correct in thinking that the earth's temperature changes on an eighty-year time scale and that these changes are driven by the sun? Most scientists remain skeptical because no physical mechanism has been proposed tying solar output to the length of the sunspot cycle. Others say that the strong similarity between the length of the sunspot cycle and the earth's temperature could be a coincidence.

In addition to the twenty-two-year solar cycle, however, change on a longer time scale has been documented. Between 1660 and 1720, sunspots disappeared altogether. Auroras, which are created when charged particles driven out from the sunspots enter the earth's upper atmosphere, were also absent from the skies during this period. Further, we know from measurements of carbon 14 in tree rings that this radioactive element, produced by cosmic rays bombarding the atmosphere, increased substantially during this time. Normally, charged particles streaming outward from sunspots create a magnetic shield that deflects cosmic rays away from the earth and the inner planets. From 1660 to 1720, this magnetic shield failed, permitting a larger number of cosmic rays to strike our atmosphere and form an unusually large number of radioactive carbon atoms.

An engraving made in the 1850s shows the glacier above the French village of Argentière reaching down into the valley.
Collection Paul Payot, Conservatoire d'Art et d'Histoire, Haute-Savoie/Denis Rigault

By 1966, the Argentière glacier had retreated, and trees were growing where the ice once flowed.
Madeleine Le Roy Ladurie/Bibliotèque Nationale

From the record of radiocarbon locked up in tree rings, we can identify two even earlier periods of reduced sunspot activity: the Wolf sunspot minimum, from about 1260 to about 1320, and the Spörer sunspot minimum, from about 1400 to 1540. These three periods span a major portion of the Little Ice Age, but the last ended more than a hundred years before the Little Ice Age did—too long a time lag. This mismatch in timing and the small change in the sun's energy output (as measured by satellites over the last solar cycle) make a link between the Little Ice Age and the absence of sunspots unlikely. But the partial match prevents a firm rejection of the sun as a cause of the earth's natural temperature changes.

What about volcanic eruptions? Major volcanic eruptions occur roughly once per decade. Most have little effect on the climate, but occasionally an eruption blasts a large volume of sulfur dioxide high into the stratosphere. Within a month or two, the sulfur dioxide is transformed into droplets of sulfuric acid, which remain aloft in the stratosphere for a year or more. These tiny spheres reflect sunlight away from the earth, cooling the planet. Hansen and his colleagues predict that the recent eruption of Mount Pinatubo in the Philippines (which shot more sulfur dioxide into the upper atmosphere than any other eruption this century) will cool the planet about one degree Fahrenheit over the next two years.

Could the Little Ice Age have been caused by 500 years of intense volcanism releasing copious amounts of sulfur dioxide? This seems implausible, as the world's 100 or so major volcanoes erupt independently of one another and no mechanism exists that could cause them all to erupt with greater frequency. Therefore, the chance is slim that one long interval would be followed by a similar period of lesser activity.

Fortunately, a record is available in ice cores to check this assumption. When the droplets of sulfuric acid from a volcanic eruption drift down from the stratosphere,

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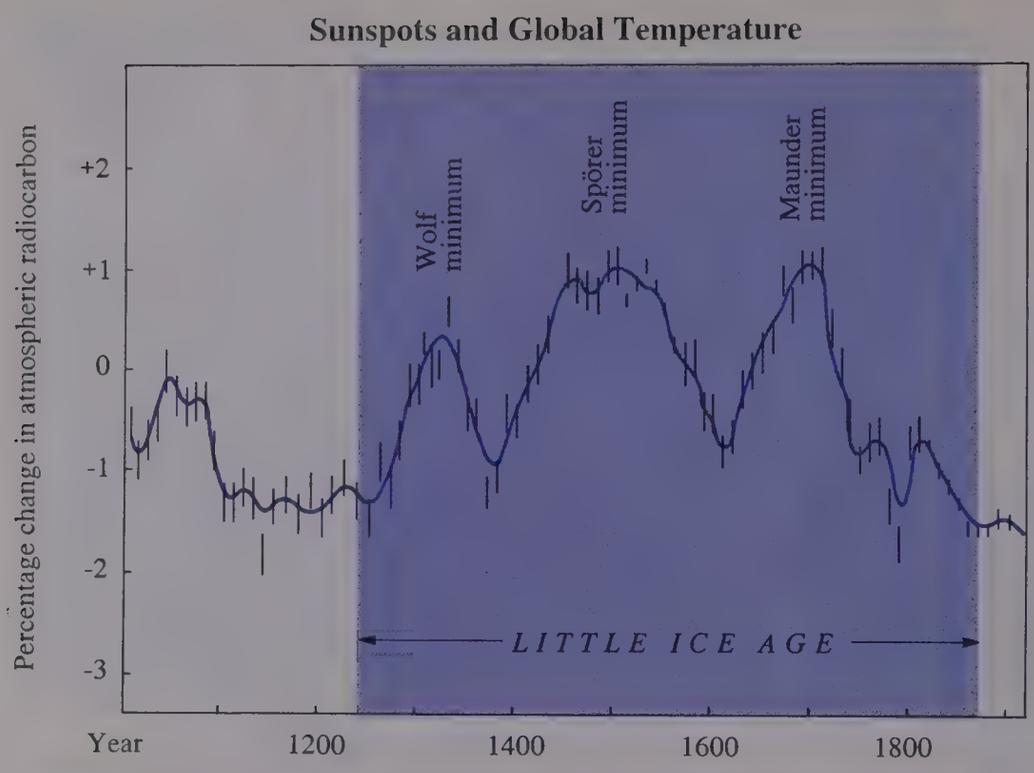

During the Little Ice Age, levels of radiocarbon in tree rings indirectly recorded three periods when sunspots all but disappeared. Sunspot minimums correspond to a slight decrease in the sun's energy output.

they are quickly incorporated into raindrops and snowflakes and carried to the earth's surface. So, in the years immediately following a major volcanic eruption, snow layers rich in sulfuric acid are deposited on all the world's icecaps. An ice core taken from the Dye 3 site in southern Greenland reveals that at about the time of the transition from the Medieval Warm to the Little Ice Age the acid content in the ice doubled. On the other hand, low acidity from 1750 to 1780 (during a time of cold weather) and the relatively high acidity from 1870 to 1920 (when the climate was warming) do not fit the pattern of climate change. Therefore, no strong correlation exists between the trends in volcanic sulfur dioxide and the trend in the earth's temperature.

The last of the three mechanisms that might account for the natural variations in the earth's temperature is a dramatic shift in the way the planet's ocean and wind currents operate. Of the three mechanisms, this one is the hardest to build a case around because we have only a rudimentary understanding of how the interacting elements of the earth's climate system might cause natural fluctuations in temperature. The only well-documented example of such a mechanism is the El Niño cycle, in which winds and ocean currents cause the temperatures of the surface waters of the eastern equatorial Pacific to alternate between warm and cold. The cycle was first noticed because of the severe drops in fish production along the west coast of South America during the warm episodes. Since the timing between these disruptive events ranges from three to seven years, scientists became interested in predicting their arrival. What emerged from these studies is that El Niño cycles are the product of a complex interaction between winds and ocean currents. The importance of this discovery to the global warming debate is that it raises the possibility that cycles involving larger-scale interactions between the atmosphere and oceans—over longer periods—may play an important role. If the earth's temperature is being pushed up and down by such an internal cycle, our chances of determining what would have happened in the absence of the extra greenhouse gases are indeed slim.

Again the judge would become restive and call a halt to this line of evidence as well. At this point he would likely dismiss the case and suggest that the litigants return a decade from now when additional evidence regarding the warming trend has accumulated.

Sununu would deem this decision a victory, for it would provide an excuse to delay actions directed toward reductions in carbon dioxide emissions. On the other hand, Hansen could surely maintain that in the absence of proof that the world is not warming at the rate predicted by computer simulations, we should follow the standard applied to other environmental threats and rule on the side of caution. Instead of placing the burden of proof on the environmentalists, the proponents of "business as usual" should be obliged to prove that the unfettered release of greenhouse gases will *not* significantly warm the planet. And such proof does not exist; the balance of scientific opinion is that business as usual will alter the climate.

The debate over global warming is merely a small skirmish that marks the beginning of a far broader war. Many of the things that we could do to curb the buildup of greenhouse gases—such as conserving energy, switching to renewable energy sources, or increasing our use of nuclear power—will be stopgap measures if the underlying problem of population growth is not addressed. World population is now 5.5 billion and growing by about 1.8 percent every year. If this rate is not substantially reduced, world population will double by the year 2030. If by that time the rate of population growth has not been greatly reduced, we run the risk that the population will skyrocket to 20 billion or more before it finally levels off. Each additional person adds to the pressure to increase the use of fossil fuels, pumping ever larger amounts of carbon dioxide into the atmosphere. In countries such as the United States and Canada, where per capita energy consumption is the highest in the world, each person, on average, adds twenty tons of carbon dioxide a year to the atmosphere. In developing countries, where most of the population growth will occur, per capita energy consumption is much smaller, with less than three tons of carbon dioxide emitted per person. But as these countries strive to better the lot of their citizens through industrialization, their energy demands will climb. Most of the increase will be met by burning fossil fuels, particularly coal, which releases more carbon dioxide per unit of energy produced than oil or gas. Therefore, annual emissions of greenhouse gases are likely to increase.

We are rapidly approaching a limit beyond which we cannot maintain our numbers without long-term damage to our planet's environment and its remaining wildlife and to the quality of life of its human populations. While Sununu may be particularly shortsighted with regard to the effects of greenhouse gases on the climate, most of the world's leaders are shortsighted with regard to the population problem. They seem to ignore it completely. I hope the concern about global warming will force us to develop a broader perspective of our planet's future—one that will include the reality of the population bomb. Only then will we be able to begin the extraordinarily difficult task of defusing it. □

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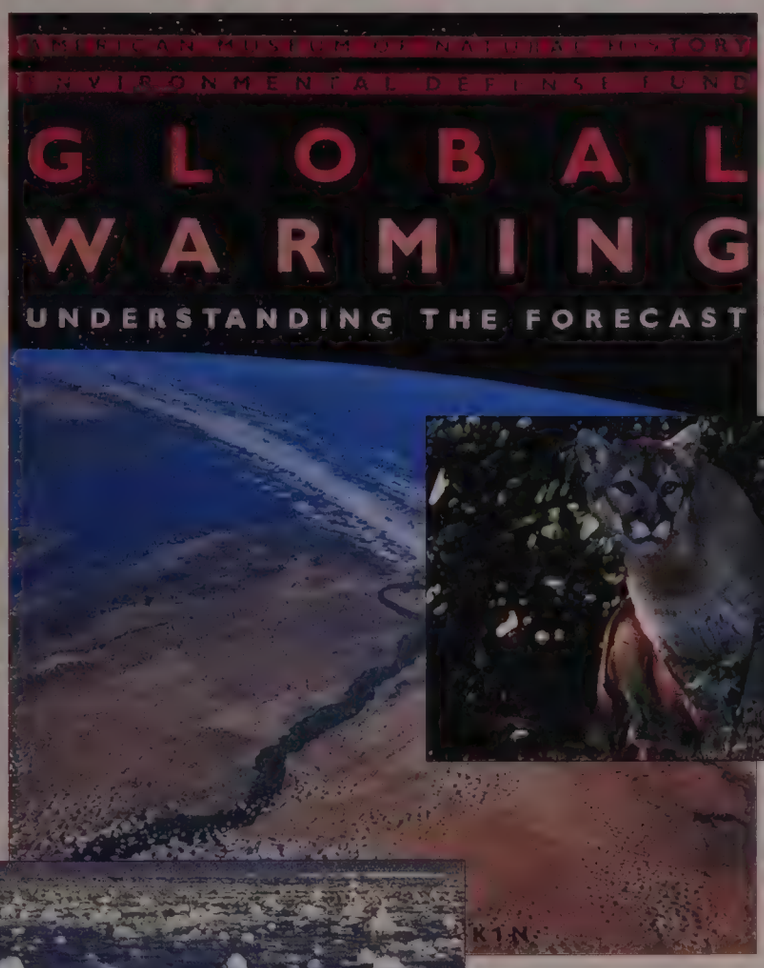

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Does the Stoneless Plum Instruct the Thinking Reed?

Or, how Luther Burbank came up with his flawed vision of a genetically superior American race

by Stephen Jay Gould

A distinctively American form of genius combines personal brilliance with promotional hokum and mountains of hard work. We note varying balances among the three essential ingredients: Barnum is our prototype for stressing the hokum, Edison for the diligence (as in his justifiably famous quip that genius is one percent inspiration and 99 percent perspiration). Luther Burbank (1849–1926) may represent the finest balance of all three factors. He wished to convert American deserts to rangeland by breeding a spineless cactus as cattle fodder. He hybridized two spontaneous mutants—one without prickles on the leaves and the other with no thorns on the young shoots—but he was never able to eliminate spines completely. Nevertheless, in public performances, he would rub his cheek against a "prop" cactus made so smooth by demonstrations that all residual spines had long since worn away.

Yet Burbank's successes made him the greatest plant breeder in American history. An astonishing string of triumphs fostered his reputation as a wizard with a magic wand for transformation—an exaggeration that Burbank, with his taste for publicity, learned to exploit to great advantage. As a young man, he developed the Burbank potato in his native Massachusetts and used the proceeds to bankroll his larger, lifetime operation in California. Here he "created" his stoneless plums, white blackberries, the (almost) spineless cactus, the giant Shasta daisy, the fire poppy, and the Burbank rose.

These triumphs reflected the other two components of American genius. For his brilliance, Burbank had an unparalleled eye for the most minute useful variation. He could scan a field of daisies or an orchard of plums and pick the plant with a slight edge for improving the breed. For his industry, no one worked at Burbank's scale, and with such zealous energy. Contrary to the hype that enveloped him, Burbank performed no miracles. He evoked nothing new from nature. He just worked harder—far harder than anyone else—with the two tried and trusted techniques of breeding: hybridization and selection. With his uncanny eye and unparalleled judgment, he would make novel plants by mixing desired traits of two or more varieties in hybrid offspring. He would then grow field upon field of hybrids, always looking for the rare plant that would emphasize all the favorable characters and suppress the undesirable features. For example, he produced his stoneless plum by crossing productive and richly fruited (but conventionally pitted) lines with a curious variety known in France since the sixteenth century but treated as useless for its poor and unproductive fruits—the *prune sans noyau* (seedless plum). By repeated cycles of crossing and selection, extending for more than a decade, Burbank managed to produce a large fruit with a stoneless pit.

Burbank fit the mold of populist hero in yet another way: he wrote very little, preferring to nurture his fame by a plethora of proven products and occasional oracular pronouncements. He did, of course, publish catalogs to push his horticultural achievements, and he did write a few short pieces for agricultural journals. But his longest and most noted article, published by *Century* magazine in 1906 and reissued as a small book in 1907, treated the quite different subject of eugenics. I have wanted to study this work for years and finally managed to buy a copy last month. The intriguing title had long piqued my interest: *The Training of the Human Plant*. We may rightly suspect that Burbank's "alien" topic for his longest written work did not stray so far from his usual concerns after all.

My essay, while not eschewing the details of spuds and roses, is primarily a commentary upon two pitfalls frequently encountered in scientific (and much other) reasoning: misleading taxonomy and false analogy. I shall treat the latter in analyzing Burbank's article, but consider our usual attitude toward eugenics itself as an example of the former danger—false categorization.

We usually view eugenics as a failed ideology of political conservatives. We do this, I suppose, for two major reasons. First, eugenics sought to reform society by improving hereditary traits through controls upon breeding (whether forced or voluntary)—and hereditarianism is a conservative strategy par excellence (people get what they deserve by birth; don't look to governmental decrees or handouts for any realignment). Second, the major consumer of eugenics in one extreme form, a certain Mr. Hitler, could scarcely be accused of liberal biases.

But the eugenics movement resists cramping into a single, unambiguous political box (and I often wonder how well right and left, liberal and conservative, really work as labels for any opposed pair of boxes). Supporters of eugenics formed a diverse and powerful movement during the early years of our century. Hardly any group owning a single name could have been more motley in all other respects. Politics always makes strange bedfellows, but the range of eugenical support must have generated some legendary pillow

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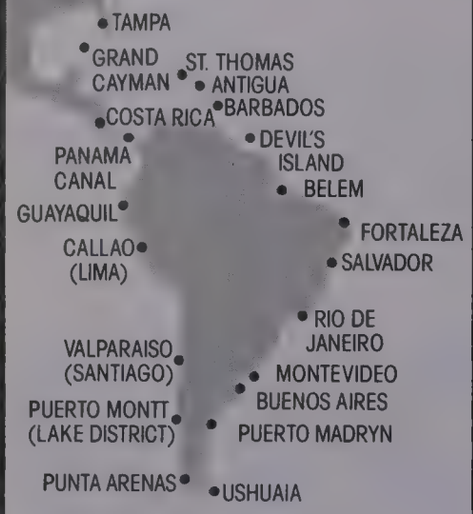

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fights before "lights out." The movement spanned a full spectrum, from hereditarian hardheads who wanted to sterilize the handicapped, the diseased, and even the merely impoverished, to Fabian idealists who hoped to persuade smart and gentle people to have more kids. For anyone with a residual affection for the false equation of eugenics with antediluvian conservatism, consider just one cardinal fact. When the Supreme Court, in the greatest victory of the American eugenics movement, upheld compulsory sterilization of the mentally unfit in 1927, all liberal justices voted aye; the single dissent to this 8 to 1 ruling was filed by the Court's most conservative member, a Catholic upholding his church's position on reproductive controls.

I mention this political diversity because Luther Burbank's book may be the most influential document of its time for a phenomenon that could not exist by the usual false correlations: liberal eugenics. By his choice of title, *The Training of the Human Plant,* Burbank prepared the ground for his grand, and ultimately false, analogy and also staked out the "liberal" field by emphasizing nurture through life rather than strict and unalterable hereditary nature.

Burbank's tract is a rigid and elaborate point-for-point comparison of his vision for improvement in human society with what he thought he was doing in developing new lines of plants. (Burbank possessed an odd streak of modesty amid his confident self-promotion, for he falsely attributed a key aspect of his own transforming skill to nature's intrinsic mechanisms. We shall see that the error of his eugenic argument lies both in his false analogy with plant breeding and in his misunderstanding of reasons for his own horticultural successes.)

Burbank begins his tract with a recommendation that followed his own first step in producing new lines of plants, but that also must have induced apoplectic rage among more conservative brethren in the eugenics movement. Burbank achieved his popular reputation as a wizard, sage, or alchemist because people thought that he could produce absolute novelty, virtually at will. In fact, he introduced almost every "new" trait by directed immigration—that is, by importing favorable features from other lineages through hybridization. By analogy, Burbank viewed his contemporary America as a land of opportunity for improvement unparalleled in human history. The Statue of Liberty lifted her lamp beside the golden door, and Ellis Island overflowed with a great tide of European immigrants. Burbank titled chapter 1 "The Mingling of Races" and began with an explicit analogy:

I have constantly been impressed with the similarity between the organization and development of plant and human life. . . . I

have come to find in the crossing of species and in selection, wisely directed, a great and powerful instrument for the transformation of the vegetable kingdom along lines that lead constantly upward. . . . Let me now lay emphasis on the opportunity now presented in the United States for observing and, if we are wise, aiding in what I think it fair to say is the grandest opportunity ever presented of developing the finest race the world has ever known out of the vast mingling of races brought here by immigration.

In context, this was a stunningly radical proposal. Conservatives, in the eugenics movement and elsewhere, had embraced agitation against immigration as one of their most passionate issues—lest our virile, virtuous, and intelligent "native" stock (meaning "northern European," not truly Native American) be diluted to folly and ineptitude by breeding with the inferior hordes now swamping us from southern and eastern Europe (my own ancestors all arrived from Hungary, Poland, and Russia during the decade of Burbank's book, so I confess some personal sensitivity to the issue). These nativists hoped to stem the tide of immigration to a trickle and, above all, to keep those already here from miscegenation. Let them work in the factories and sweatshops; let the Jew cut my cloth, the Italian my hair, and let the Irishwoman wash my floor; but keep them away from my sons and daughters. Can you imagine how Burbank's proposal for the benefits of interbreeding played in such circles?

Let me not exaggerate. I am not sure how far Burbank meant to go. He clearly favors mixing of different *European* stocks but is conspicuously silent about people of other colors (there was, I suspect, an unstated limit to radicalism in such a racist age). Moreover, Burbank is no egalitarian in a modern sense. He accepts different intrinsic worths and temperaments among European groups (with the traditional contrast of sturdy Nordics and emotional Mediterraneans) but still favors their combination so that the various goods may be sorted into one superior stock:

> Look at the material on which to draw! Here is the North, powerful, virile, aggressive, blended with the luxurious, ease-loving, more impetuous South. Again you have the emerging of a cold phlegmatic temperament with one mercurial and volatile. Still again the union of great native mental strength, developed or undeveloped, with bodily vigor, but with inferior mind.

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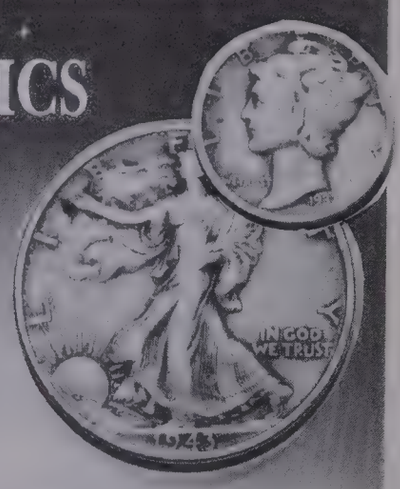

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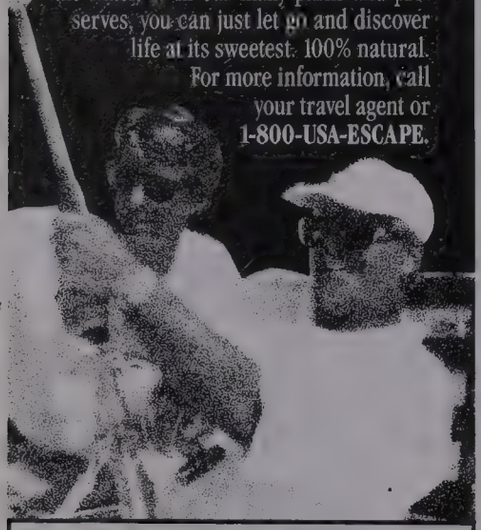

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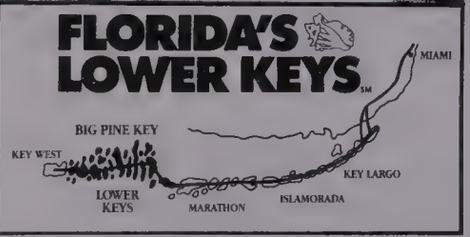

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creates raw material by mingling formerly separate traits into single lineages. By itself, with no follow-up, mixing will only create chaos and make matters worse.

The mere crossing of species, unaccompanied by selection, wise supervision, intelligent care, and the utmost patience, is not likely to result in marked good, and may result in vast harm. Unorganized effort is often most vicious in its tendencies.

How then shall eugenics proceed after this vast and wholesale mixing of European stocks? Since Burbank, by title and intent, wishes to improve humans exactly as he makes better plants, further progress must follow his horticultural protocol. Burbank outlined a four-step process for improving plant lines, and he transferred this entire apparatus to his vision of human betterment. Burbank was not a modest man—and the poignancy of this story (also the reason for logical failure of his eugenic argument) lies in the fact that he was a far better plant breeder than even he realized. For he actually accomplished all his feats with only two of his four steps, while he thought that nature acted as his auxiliary via two additional, but nonexistent, processes. Ironically, he rooted the humanistic and "liberal" heart of his eugenic program in the two illusory processes—while his true protocol in horticulture debarred, by his own moral values, any attempted transfer to human improvement, thus eradicating his own analogical argument.

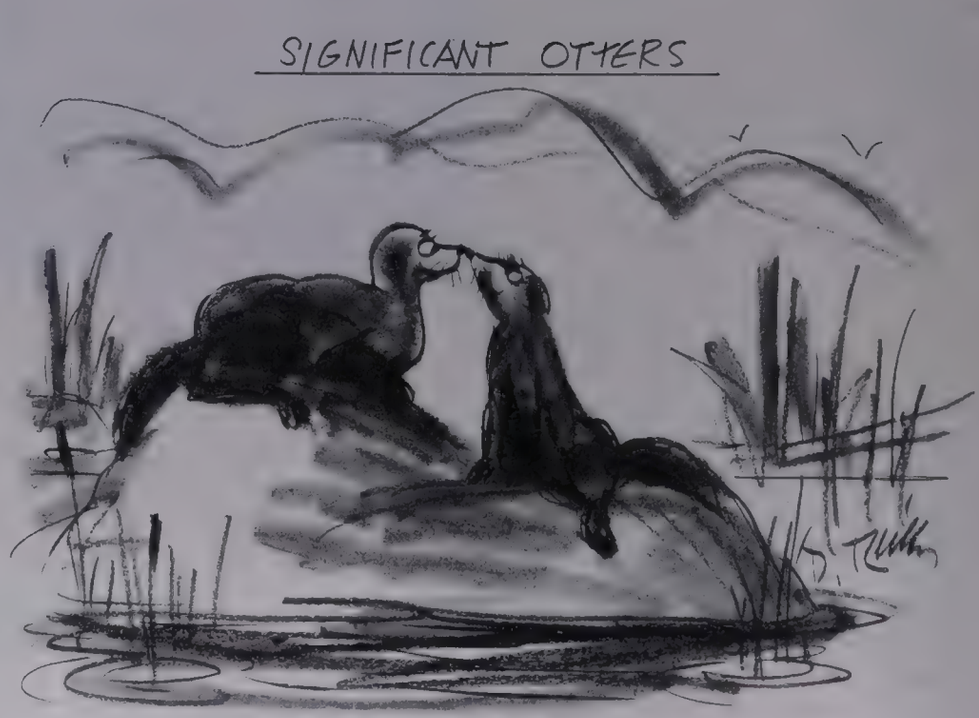
Burbank epitomizes his four-stage method in setting out an argument for transfer to human society:

There is not a single desirable attribute which, lacking in a plant, may not be bred into it. Choose what improvement you wish in a flower, a fruit, or a tree, and by crossing, selection, cultivation, and persistence you can fix this desired trait irrevocably.

Let us consider these four steps in order:

1. *Crossing.* Burbank, as stated before, performed no miracles of novel evocation. He introduced new traits into old lines by hybridization with different stocks already bearing the desired features. Just as hybridization stirs the raw material for horticultural improvement into a single line, miscegenation of immigrant stocks will produce the world's finest people in America.

2. *Selection.* Crossing only increases the range of variation in offspring and does not produce any mean alteration by itself. This net change, called improvement when regulated to human advantage, results from selection—the destruction of most plants and the breeding of future generations from just a few that happen to possess a desired mixture of traits. Darwin, of course, called nature's unconscious version of this process natural selection. In either mode, natural or horticultural, selection is a rigorous process. Many are called, and very few chosen. Rapid improvement demands the exclusion of nearly all from reproduction, with death as the surest means of prevention (although sterilization, celibacy, and other analogues are potentially available). The horticulturist uproots; nature generally eliminates. The transfer of this harsh process from nature's amoral realm to human life has been—and ever so rightly in my view—the fatal flaw of all traditional programs in eugenics. Selection is nature's primary path for genetic change in populations, and this process, applied in the ethical realm of human society, is un-



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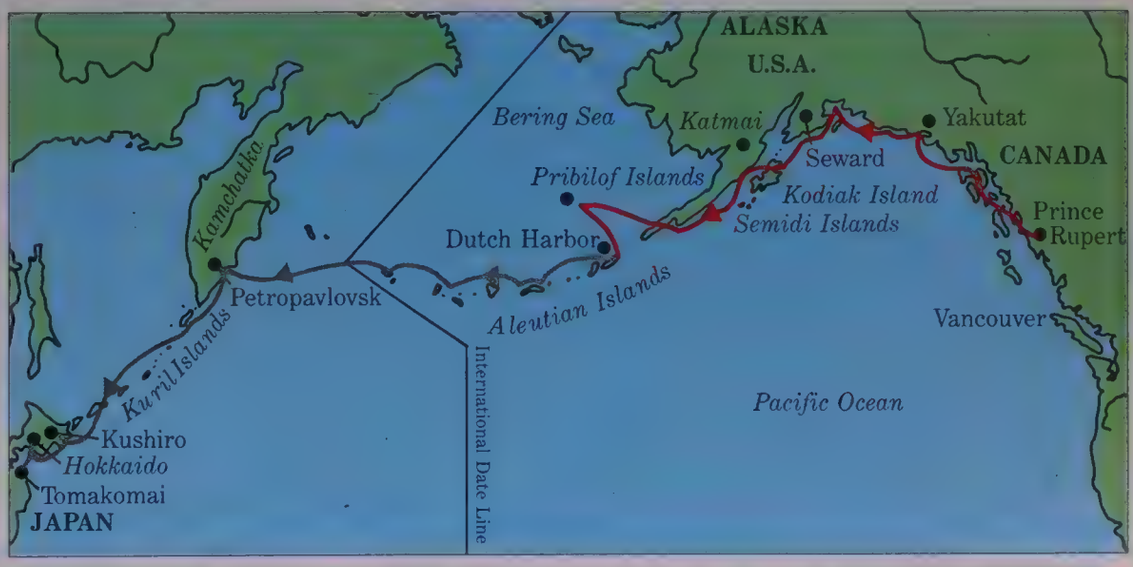

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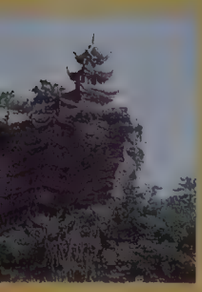

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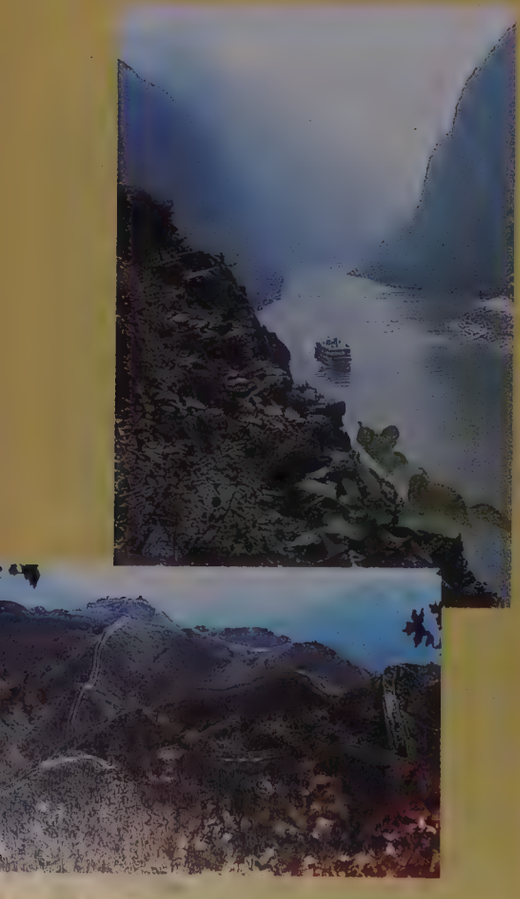

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acceptably cruel and authoritarian (for someone must play the role of Lord High Uprooter).

3. *Cultivation.* No one doubts the salutary role of cultivation—that is, good environment—in sustaining the health and vigor of an individual plant. But what role can good environment play in genetic improvement, for none of the virtues acquired during life are passed to offspring in Mendel's world? (Proper cultivation keeps a plant vigorous for reproduction, but this aspect of environment only acts as input to selection and gives nurture no independent status in improvement.) Burbank, however, was a Lamarckian. He believed that characters acquired by good rearing during an organism's life could be passed to offspring—and that improvement would accumulate through this transfer, generation by generation and step by constant step.

4. *Persistence.* For Lamarckians, persistence is merely the furtherance of cultivation. Lamarckian advances come little by little; a breeder (or nature) must keep at it for generations, and unremittingly. Mendelian characters are intrinsic; bad environment does not dilute them (although extreme malfeasance, of course, may kill the organism and terminate the experiment). But Lamarckian traits can be dismembered by generations of neglect just as good rearing had built them sequentially.

With these last two categories, we arrive at the crux and idiosyncrasy of Burbank's eugenic argument—and its ultimate fallacy. Burbank was quite wrong about these categories. No Lamarckian component helped his plant breeds along. Nature is Mendelian and does not work in this hopeful manner. In fact, Burbank bred plants on thoroughly Darwinian principles, using only the first two categories of his own list: crossing to mix the Mendelian characters of different lines into hybrid offspring, and selection to collect and accentuate the traits he sought. But he was so damned good at the art of breeding, so much better than anyone else, and this excellence—not fully acknowledged—led him to a false but unshakable conviction that nature must be helping out in some other way! He could not believe that he was doing all this himself, merely by selecting so rigorously and on such a grand scale.

And Burbank was nothing if not zealous in the scope of his selection and the heapsize of his hecatomb. He would sacrifice fields of plants to find just one worth propagating. Let just one eyewitness report suffice as testimony to his diligence. The source is particularly interesting—Hugo de Vries, the great Dutch botanist and one of the three scientists who rediscovered Mendel's work. (De Vries, who visited California twice, was awestruck by Burbank's practical skills but dumbstruck

by his stubbornness in sticking with Lamarckism as Mendelism marched to triumph, with de Vries as a major general in the campaign):

His methods are hybridization and selection in the broadest sense and on the largest scale. One very illustrative example of his methods must suffice to convey an idea of the work necessary to produce a new race of superlative excellency. Forty thousand blackberry and raspberry hybrids were produced and grown until the fruit matured. Then from the whole lot a single variety was chosen as the best. It is now known under the name of "Paradox." All others were uprooted with their crop of ripening berries, heaped up into a pile twelve feet wide, fourteen feet high and twenty-two feet long, and burned. Nothing remains of that expensive and lengthy experiment, except the one parent-plant of the new variety.

Returning to the *Training of the Human Plant,* Burbank's major emphasis, the source of his liberal tilt on eugenics, lies in analogy with the third and fourth phases (alas, the illusory ones) of his supposed horticultural protocol: cultivation and persistence. (I am leaving selection aside for the moment—for there's the rub, as Burbank knew only too well, for he also tried to treat the question as a side issue.)

Burbank makes his plea for healthy childhood environments by his usual comparison with plants:

If you are cultivating a plant, developing it into something finer and nobler, you must love it, not hate it; be gentle with it, not abusive; be firm, never harsh. I give plants . . . the best possible environment. So should it be with a child, if you want to develop it in right ways. Let the children have music, let them have pictures, let them have laughter.

Burbank's formula for good rearing is strictly Arcadian—a passionately romanticized idyll of clean country living without intellectual pressure. (Burbank wanted no formal schooling before age ten and continually stresses this single proposal as the beginning, if not the panacea, for all reform.) Just one quotation to give the flavor of his florid prose:

Every child should have mud pies, grasshoppers, water-bugs, tadpoles, frogs, mud-turtles, elderberries, wild strawberries, acorns, chestnuts, tress to climb, brooks to wade in, water-lilies, woodchucks, bats, bees, butterflies, various animals to pet, hay-fields, pinecones, rocks to roll, sand, snakes, huckleberries and hornets; and any child who has been deprived of these has been deprived of the best part of his education. By being well acquainted with all these they come into most intimate harmony with nature, whose lessons are, of course, natural and wholesome.

There is, of course, nothing unusual in urging healthy rearing for children. What reformer would recommend anything else? But remember: this is a eugenic tract, an argument about *genetic* improvement. Good rearing must therefore be advocated as a direct hereditary benefit to future generations—a theme making little sense in Mendel and Darwin's world. But Burbank was a Lamarckian, and he therefore stressed exemplary rearing not only for its obvious value to direct beneficiaries but also, and especially, for its Lamarckian transfer to future generations of genetically improved stock. Thus, for Burbank, good nurture now is the key to better nature for posterity:

Heredity is not the dark specter which some people have thought—merciless and unchangeable, the embodiment of Fate itself. . . . My own studies have led me to be assured that heredity is only the sum of all past environment, in other words environment is the architect of heredity; and I am assured of another fact: acquired characters are transmitted and—even further—that all characters which are transmitted have been acquired.

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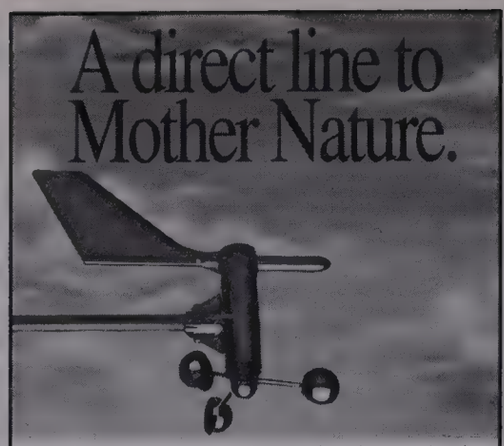

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factor, the bugbear of all liberal eugenics and the actual source of Burbank's major achievements in horticulture: Darwin's force of selection. How can you talk about genetic improvement unless you are willing to prevent reproduction of those deemed unfit? And how can you even envisage a humane eugenics if the improvement of people must work like nature or horticulture where, undeniably, the overwhelming majority of individuals fall into the category of dispensable *and* dispensed?

Burbank skirts around this issue in his tract. At one point, he does admit a preference for laws on prohibition of marriage among the "unfit"—a quite stunning exception to his general defense of civil liberties when you consider the ethically repugnant issues of who gets included and who decides: "It would, if possible, be best absolutely to prohibit in every State in the Union the marriage of the physically, mentally and morally unfit."

But, for the most part, Burbank speaks little about this most powerful force of all. He senses the moral dilemma and, for once, strays away from the analogy with nature and horticulture. What of physical weakness: "Shall we, as some have advocated, even from Spartan days, hold that the weaklings should be destroyed? No." He then acknowledges the most difficult question of all: "But with those who are mentally defective—ah, here is the hardest question of all—what shall be done with them?" And for once, decency triumphs over the logic of his own argument. Here Burbank makes an exception and admits the failure of his pervasive analogy:

> In the case of human beings in whom the light of reason does not burn, those who, apparently, can never be other than a burden, shall they be eliminated from the race? Go to the mother of an imbecile child and get your answer. No; here the analogy must cease.

Yet Burbank found a way out—not an ideal solution, but a workable exit that preserved his liberal version of eugenics. Human morality must slow the process of improvement, for we cannot bear the hecatomb that any effective selection imposes. But if heredity is Lamarckian, we may allow the unfit to live, even to reproduce, and still make sure, if slower, progress. For good environment induces improvement, and these benefits are passed on as altered heredity. Nurture the unfit for enough generations and they will eventually become genetically worthy:

> When certain hereditary tendencies are almost indelibly ingrained, environment will have a hard battle to effect a change in the

child; but that a change can be wrought by the surroundings we all know. The particular subject may at first be stubborn against these influences, but repeated application of the same modifying forces in succeeding generations will at last accomplish the desired object in the child as it does in the plant. No one shall say what great results for the good of the race may not be attained in the cultivation of abnormal children, transforming them into normal ones.

My exposition may have been lengthy, but the outcome and moral of the story is short and unambiguous. Nature, in the wild or in horticulture, works on Darwinian, not Lamarckian, principles. Acquired characters are not inherited, and desired improvement occurs by rigorous selection with elimination of the vast majority from the reproductive stream. Burbank could develop new breeds, but he could not alter the rules. He actually worked by extensive hybridization and uncompromising selection, although his own success fooled him into thinking that nature helped his efforts via Lamarckian inheritance. The Lamarckian theme sets the keystone for Burbank's liberal eugenics, based on the *genetic* effects of good nurturing. The fallacy of Lamarckism spells the utter destruction of his argument.

Yet a deeper error pervades the entire enterprise, of which Burbank's tract represents but one example in a continuing tradition—the attempt to pattern human ethical conduct by aping nature's way. Burbank was wrong about nature's mode of action. But even if he had been right, his effort would have been just as misguided. Nature's factuality is not, and cannot be, our morality. We must know how nature works in order to understand ourselves and recognize our limits and possibilities in a tough universe, but why should a process that regulated 3.5 billion years of living creatures without explicit ethical systems provide all the answers for a species that evolved only a geological second ago, and then changed the rules by introducing such new and interesting concepts as justice and righteousness?

In his famous 1893 essay on *Evolution and Ethics,* the classic statement on nature's amorality, Thomas Henry Huxley praised Darwinism for its effectiveness, speaking of "the struggle for existence, which had done such admirable work in cosmic nature." But he quickly added that "the cosmic process has no sort of relation to moral ends." He closes with an argument that human intelligence may choose either to follow nature or, if judging that proper ethics requires another course, hope to use the fragile gift of mind as the only available path to transcendence:

> In virtue of his intelligence, the dwarf bends the Titan to his will. In every family, in every polity that has been established, the cosmic process in man has been restrained and otherwise modified by law and custom.

Burbank was hard at work in California when Huxley wrote his essay, but Darwin's bulldog was not casting his thoughts westward when he argued that human intelligence debars nature as the simple arbiter of ethical questions. Still, I am delighted to report that Huxley, in an unconscious touché to Burbank, used a botanical metaphor—and a grand classic at that—to secure his most important point, a message every bit as vital today:

> The history of civilization details the steps by which men have succeeded in building up an artificial world within the cosmos. Fragile reed as he may be, man, as Pascal says, is a thinking reed: there lies within him a fund of energy, operating intelligently and so far akin to that which pervades the universe, that it is competent to influence and modify the cosmic process.

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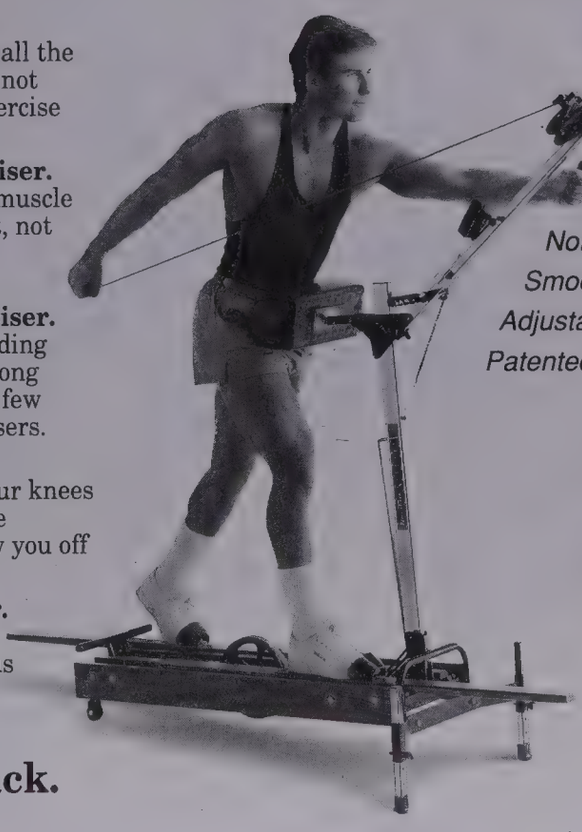

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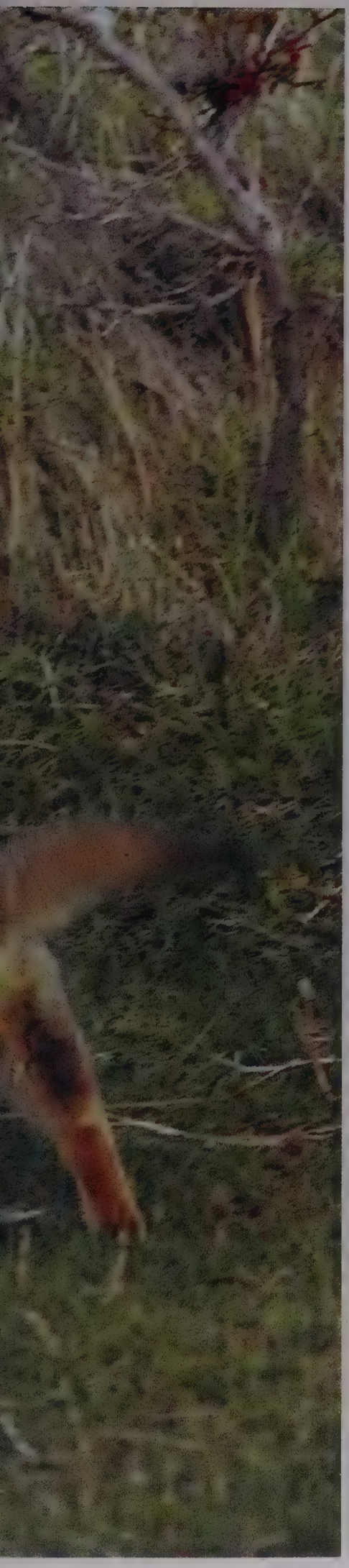

Gray fox pups, left, beg a meal from their mother. If her catch is small, she regurgitates it into their gaping mouths. Below: A pup makes off with part of an upland goose egg wrested from its littermates.

Patagonia's Little Foxes

Resourceful predators, they can thrive on berries, beetles, and scorpions

Text and photographs by Warren E. Johnson

Patagonia is a land of jagged glacial peaks and endless pampas, of gale-force summer winds and calm, frosty winters. Its rugged beauty has captivated naturalists from Charles Darwin to George Gaylord Simpson, both of whom admired its diverse wildlife, including the unique guanacos and rheas. This rich fauna includes two species of foxes, but unlike their northern relatives, very little had been known about them. In January 1985, assisted by several dedicated helpers and by modern radiotelemetry techniques, I began a four-year field study of their lives.

I arrived at the Torres del Paine National Park in midsummer, after driving for hours along bumpy dirt roads, and was awed by the spectacular Paine Range thrusting 8,000 to 10,000 feet above the vast pampas. I was also rewarded on my first day with a glimpse of a South American gray fox—the species I would get to know best.

Remarkably unconcerned with my presence, the diminutive fox continued its erratic path through the low, rounded *mata barrosa* bushes and grass clumps. Periodically, it paused, sniffed, and with a quick bite snatched up a dung beetle from the sandy soil. Although these insects are abundant, I could not imagine them providing more than a paltry snack for what I

had imagined was a meat-loving canid. As I later discovered, these foxes are not fussy and will eat almost anything they can digest.

Referred to locally as the *zorro chilla* or *zorro gris,* the gray fox is one of nine fox species endemic to South America, two of which are found in the park. It is relatively small, standing about sixteen inches high at the shoulder and weighing only six and a half to nine pounds. After several months in the area, I finally got to observe its more evasive and larger, coyote-sized relative: the culpeo, or colored fox, named for its tawny head and legs and grizzled gray back.

Unlike European and North American species, Patagonian foxes do not belong to the genus *Vulpes;* their ancestors split from a more wolflike lineage about seven million years ago, before migrating across the Isthmus of Panama. The Patagonian gray fox evolved into its present form in South America between one and two million years ago.

At the center of the fox's social system is a breeding pair, which maintains an exclusive year-round territory. Over time, however, I observed that this basic pattern is flexible, with a single male occasionally consorting with more than one female. She may be an offspring from a previous litter or another lactating female with or without her own pups. In either case, she serves as a nonbreeding helper that assists in rearing the young. Most smaller canids have a similar system.

In August, at the beginning of the Patagonian spring, while snow and ice still cover much of the vegetation, gray foxes abandon their winter solitude and spend more and more time with a mate. The coming breeding season is also heralded vocally, by their frail barks and high-pitched yelps, which can be heard during the long, sixteen-hour winter night. These calls, continued throughout the night only during breeding season, may serve to announce the location of a pair's territory.

By mid-October, each pair has an average of four or five young. When resources permit, a nonbreeding female helper may improve the odds that all the pups will survive. She brings in more food, provides extra protection against predators, allows the mother more foraging time, and even substitutes for her if she dies. This nonbreeding, subordinate female is allowed to stay in the familiar (and therefore less dangerous) territory in which she grew up and may eventually inherit it. From an evolutionary perspective, she may also benefit genetically by helping

A colored fox, left, pauses with part of its dinner, the head of a European hare. Hares and daisies were introduced into the region by English ranchers. Below, top: The area between Lake Sarmiento and the base of the Paine Range is prime fox habitat. Bottom: After foraging for beetles in the sandy soil, an adult gray fox rests on the pampa.

pups that are closely related to her survive, thus perpetuating her genes.

Pups begin to venture outside the den when they are four to six weeks old. Frolicsome balls of fur, they slowly expand their experience of the world. Both parents (and sometimes a helper) bring them mice, European hares, and small birds. When an adult arrives, the pups rush from the den or surrounding bushes, beating their tails wildly and begging for food. Each pup tries to be the first to get the food from the parent and then defends the provisions against littermates. Once I saw an adult bring back an upland goose egg, a particularly choice meal that inspired a more frantic scramble than usual. A fragile egg is not so easy to divide as an animal carcass, but the pups managed. One immediately secured a large section of gooey shell in its mouth, while another followed right

behind. Chased around a large bush, the first pup finally dropped the eggshell but continued running with the second still at its heels. A third pup seized its chance and the eggshell, disappearing under the bush with its prize.

Pups grow rapidly and by January begin to roam beyond the immediate vicinity of their home, which often is not the original birth den. Their initial forays are led by one of their parents, but soon they begin to venture out on their own, hunting insects and small prey.

Gray foxes' omnivorous feeding habits may help account for the species' wide distribution. By analyzing foxes' feces, I found that 90 percent of the vertebrate animals they consume are mammals. Half of these are European hares, which were introduced into southern South America in the 1880s and have since become an important staple for many of the region's predators. European hares seem also to have largely displaced the native Patagonian "hare," which is a large rodent of the guinea pig family.

Gray foxes also take many mice, small birds, frogs, and lizards and will scavenge when dead meat is available. Patagonian pumas, the largest predators in the area, frequently leave half-eaten carcasses of guanacos and domestic sheep from a ranch near the park. The foxes feast on such carrion. But from spring through fall (September through May) half of the gray fox feces I examined contained many beetles, scorpions, and other insects, and in summer and fall, numerous seeds from the berries of the calafate bush.

The principal threats to the gray fox are hunting and trapping, both legal and illegal (it is protected as endangered in some regions). Several times, following the signal of a radio-collared fox, I found only the collar hanging from a fence or branch, left by a local hunter. And once, to both my own and his surprise, I followed a transmitter signal to the saddlebag of an old gaucho who didn't quite understand why the fox his dogs had just killed had a collar and ear tags.

Besides human activities, competition with the larger culpeo may most limit the gray fox's distribution. Where both species are found, as in Torres del Paine National Park, their local territories do not overlap. Culpeos occupy areas where mice and European hares are abundant, while the smaller grays can survive in poorer environs by supplementing their diet with everything from beetles to berries. Thus, the flexibility of the gray fox enables it to live where a culpeo cannot survive, an attribute that bodes well for its future. □

Two playful gray fox pups, opposite page, explore the world near their family den. Below: A six-month-old fox tears through the underbrush in pursuit of prey.

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Quantum Leapers

Aphids take risks to satisfy ancient tastes

by Nancy A. Moran

Aphids—one of the main groups of tiny insects that suck the juices of your prized rosebush—have aroused the interest of scientists since at least 1745, when the French naturalist Charles Bonnet showed that the females could reproduce parthenogenetically—without the benefit of males and mating. All aphids reproduce this way much of the time, females producing females, the descendants of a single individual forming a natural clone. These clones are usually polyphenic, that is, they include two, three, sometimes as many as eight distinct types of individuals that look and behave very differently, even though they are genetically identical.

The different types within a clone, called morphs, usually appear at specific stages in the annual life cycle and may even live on different kinds of plants, with specialized winged forms arising when it is time to migrate between host plants. Some aphid species even have soldier morphs that defend other members of the colony, the way ant soldiers do in an ant colony. Aphids are known to migrate from elm trees to apple trees, from spindle bushes to beans, and from cottonwood trees to lettuce roots. Discovering these unusual cycles can be tricky: sometimes aphids originally classified as different species turn out to be alternative morphs of the same species. Chance discoveries often enable scattered pieces of these puzzles to be put in place.

In late summer 1986, for example, I was walking along a creek bed in the Santa Catalina Mountains, enjoying a respite from the desert heat of nearby Tucson, when I came across a sparse stand of smooth sumac, a plant familiar to me from my years in the Midwest. The leaves bore two-inch-long galls—hollow, teardrop-shaped growths—containing colonies of the sumac gall aphid, *Melaphis rhois,* which is widespread in North America. As an avid aphidologist, I wanted to find out more about this species and did so upon returning to Tucson. I learned that it was first described in the 1870s by Asa Fitch, a New York entomologist. I also discovered a paper, written by entomologist A. C. Baker in 1919, describing somewhat similar aphids an associate had collected from mosses in West Virginia. Baker speculated that these "might be the long-missing spring migrants of *rhois.*" However, he was unable to relocate colonies on mosses and so described the specimens under a new name, *M. minutus,* calling "the attention of other workers to it in the hope that someone may have the opportunity to study its life history."

The fruits of staghorn sumac, left, bloom in late summer. Above: A cross section of a newly formed sumac gall reveals the female founder, or fundatrix, of an aphid colony, whose asexually produced offspring will form a clone of genetically identical individuals.

Photographs by Dwight Kuhn

Thinking that seventy years was long enough to leave this question unresolved, I proceeded back up the mountain determined to check out Baker's suspicion. Near the sumac, on rocks and bases of tree trunks, were some mosses; close inspection revealed that they were infested with tiny aphids. Examining them under the microscope, I found them indistinguishable from the moss-feeding aphids that Baker had illustrated. Finally, to confirm their identity, I transferred aphids from the sumac galls to mosses in my laboratory's rearing chambers. They produced thriving colonies, growing to resemble the moss-living morphs I had seen in the wild.

I have been studying the species in the field and laboratory for several years, and my findings, as well as observations of related aphids by other researchers, tell us a good deal about the sumac gall aphid's life cycle. Like many other aphids, the sumac gall species is closely tied to a plant host, in this case North American sumacs, including both staghorn and smooth sumac. In June, tiny females, called fundatrices, hatch from eggs on the sumac bark and crawl to the new spring leaves,

where they settle and feed. Each fundatrix probes the upper surface of the leaf with her needlelike mouthparts, stimulating the plant tissue mechanically and perhaps even chemically. Within a few days, she induces a small depression in the leaf. This soon deepens and becomes a closed sac, called a gall, that envelops her as she continues to feed and develop.

At maturity, without mating, the fundatrix begins to develop embryos in her abdomen and gives birth to daughters, while the sac continues to grow in size to accommodate the colony. By August, a gall can contain up to 4,000 genetically identical females, the daughters and granddaughters of the original female. The pale, wingless fundatrix and her daughters live out their lives within the protective confines of the gall. But the granddaughters, which reach maturity in autumn, are a different morph: they develop wings and toughened, darker bodies. At about the same time, slits open at the top of the gall. On calm, sunny afternoons in September, these females emerge and take wing, abandoning the only world they, their mothers, and their grandmother have ever known. The wingless aphids that remain behind perish, for the growing season of the sumac, a deciduous plant, soon draws to an end.

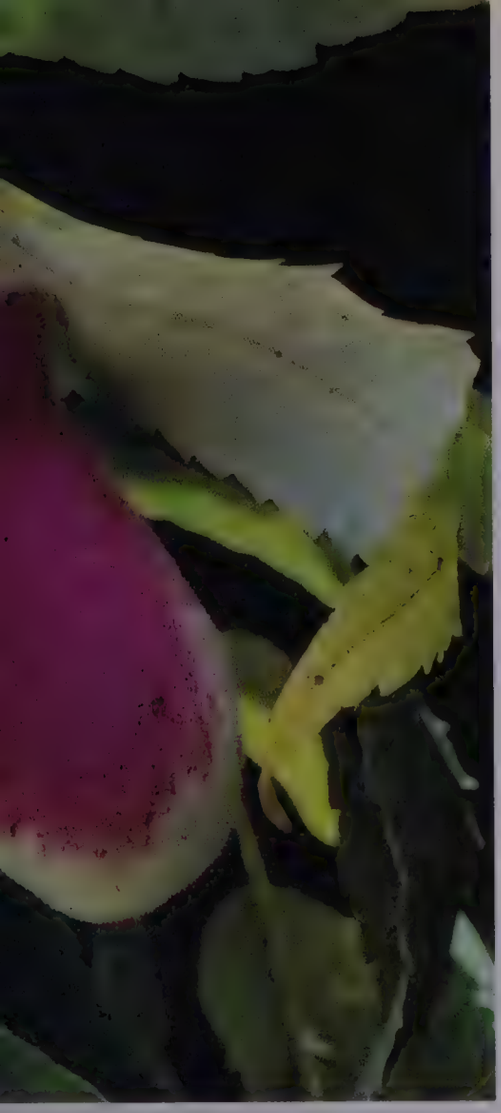
The migrant aphid, which lives only a few more days, has a single task: delivering her offspring to a moss, the alternate host plant. The migrant's digestive system has degenerated, making room for her cargo, a little bag of well-developed embryos. Like many other plant-feeding insects, she is genetically programmed to recognize the right host. When specialized sensory neurons in her antennae make contact with the appropriate mosses, the migrant aphid's behavior changes markedly. Within minutes, her abdomen begins to pulsate and she deposits a dozen or so tiny offspring. Then, her abdomen empty and shriveled and her progeny crawling about on the moss, she dies.

The newborns begin feeding, developing, and reproducing new generations parthenogenetically. Lacking the safety of a gall, each individual encases herself in waxy secretions for protection against the elements. The moss colony can therefore persist for months or even throughout the following year, surviving periods of desiccation, rain, and snow. Then in the spring of the first or second year—this seems to vary—a new generation of winged females arises in the mosses. These spring migrants, however, prefer sumac, not mosses. And they deposit a special type of wingless progeny that includes not only females but also males (the formation of the males depends on the loss of one X chromosome).

These new females and males do not feed, but mate and die within a week or less. The mating that takes place during this one sexual generation gives aphids from different colonies an opportunity to intermix and produce offspring with new genetic characteristics. After mating, the females deposit their eggs on the bark of the sumac stems. The next stage of the life cycle has yet to be fully studied: we are unsure whether the eggs develop and hatch the same spring they are deposited or whether they remain dormant for a year. But eventually they hatch into a new generation of fundatrices.

The switching of the host plants is accomplished through a whole array of special adaptations. For example, the shortening days in autumn trigger hormonal changes in the growing juveniles (or in their mothers) that lead them to mature into winged migrants that are attracted to moss rather than to the sumac upon which they developed. In spring, a comparable sequence of events insures that host preferences are again reversed.

A survey of related aphid species, their life cycles, and their preferred host plants leads me to conclude that, most likely, the early ancestors of the sumac gall aphid once lived only on sumac, depositing eggs that could survive the winter months when the host plant was dormant. For example, some relatives of the sumac gall aphid form galls on *Pistacia* trees, members of the same plant family as sumac, but use plants other than mosses as their alternate hosts. Both probably descend, therefore, from an ancestor that specialized in colonizing just the one plant family. But why would an ancestor of the sumac gall aphid have evolved to alternate between two hosts? At first appearance, this would seem a risky undertaking. Aphids are not very good fliers and cannot live long in the harsh, dry world away from their host plants. A huge proportion of the winged migrants, born and developed on one host but able to reproduce only on a completely different type of plant, must die without finding an appropriate site to deposit their



Mature galls housing aphid colonies, left, hang from sumac leaves in September. Below: Although genetically identical to the other aphids in the gall colony, the maturing granddaughters of the fundatrix have wings and darker, toughened bodies.

Photographs by Dwight Kuhn

offspring. Nevertheless, this kind of life cycle has arisen in many different aphid lineages.

Biologists often interpret such arrangements as the "optimal" solutions to prevailing environmental conditions. Applying this view to the sumac gall aphid, for example, one might expect to find that sumac is the ideal host in spring and summer and that mosses are the most nutritive in fall and winter. This is a useful starting hypothesis; but one of its limitations is that it explains everything on the basis of the present plant community and fails to take into account the past environment and possible constraints arising from past evolutionary choices.

The sumac gall aphid's host preferences were established before many modern plant groups even existed. The antiquity of the associations can be established by looking at some of this aphid's close relatives in eastern Asia. Like the North American species, these are members of the subtribe Melaphidina; the best-known Asian species is the Chinese gall aphid, *Schlechtendalia chinensis,* whose galls have been important to the Chinese for centuries as a source of black dye and tannin (the use of galls for these purposes is also the source of the term gallic acid). Chinese researchers, interested in identifying the conditions necessary for the maintenance of gall populations, have demonstrated that the Chinese species migrates to mosses as its alternate hosts, just as the sumac gall aphid does.

How did the Asian and American species come to have the same hosts and such a similar and peculiar life cycle? The only plausible answer is that they have retained these host affiliations and life cycles, along with their similarities in structure, from some common ancestor. So far so good. But the ranges of the Asian and American species are now separated by some 5,000 miles or so of ocean, corresponding to a similar break in the distribution of sumac. Even with the help of air currents, the ancestors of these aphids could not have dispersed over this distance. They must have been closer at some time in the past.

The last time this was likely was about 48 million years ago, during the Eocene epoch. Then, the planet was warmer, and many plant groups grew farther north than their relatives do now. Fossils of sumac leaves have been found in Alaska, which at that time was connected to Asia by a land bridge across the Bering Strait. The Melaphidina must have already acquired the habit of migrating between sumac and mosses by this time, before the Old World and New World species were separated.

Eocene plant communities were very different from those that prevail today. Many groups of plants that now abound in north temperate regions had not yet arisen, while some that were common are now extinct or absent. For example, the earliest known fossils confirmed as members of the sunflower family, a dominant part of most modern north temperate plant communities, are only about 30 million years old, and most diversification of that great family occurred millions of years later. On the other hand, some plants that grew along with sumac in Alaska are now confined to tropical or subtropical regions.

Thus, out of all the plants available in a modern community, sumac and mosses do not necessarily represent some optimal combination of hosts. On the contrary: the antiquity of the life cycle of the sumac gall aphid suggests that the insect has become evolutionarily "stuck," repeating its specialized alternation between hosts for millions of years, even though other plants might theoretically be more favorable.

A number of insects maintain their ancient associations with plants, while others have switched to entirely new hosts. But of all the insects that feed on plants, only

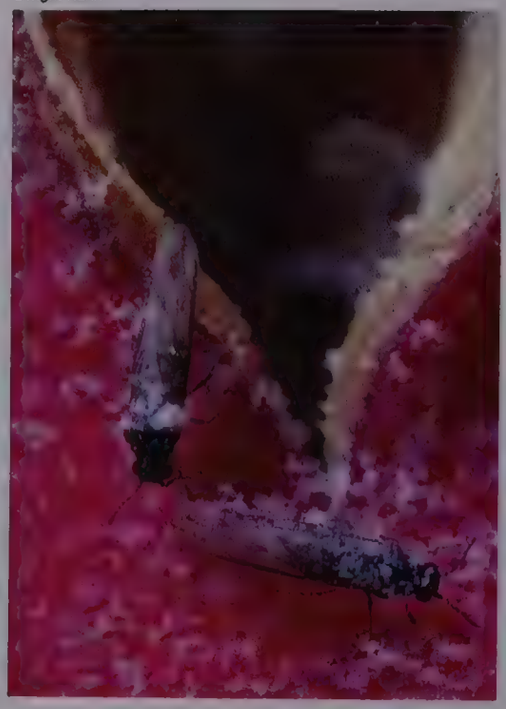
aphids ever alternate hosts. The evolutionary route through which this habit arose seems to be connected with some special feature of aphids.

The key, I believe, is that ancestral aphid species were often polyphenic, producing different morphs in response to seasonal cycles. For example, the ancestors of the sumac gall aphid may have lived exclusively on sumac, producing several morphs during the year. In the spring, the morphs may have been modified in ways that maximized their fecundity at the expense of their capacities for defense, mobility, and sensation. Such modifications—precursors of the fundatrix traits we see today—would have been well suited for the conditions encountered in early spring, when plant sap is rich in nutrients, budding leaves provide good feeding sites, and natural enemies are generally scarce. Later summer generations would have encountered more adverse conditions. The morphs produced then were probably more limited in their reproductive capacities, but better at searching out feeding sites and at defending themselves against enemies.

Polyphenism would have given the generations within the same lineage differing abilities to colonize hosts other than sumac. Special traits that enhanced the success of a fundatrix, such as the ability to form galls, also anchored her to the old host, the sumac. The late summer generation, being more adept at finding new feeding sites or more tolerant of less-than-ideal conditions, was more likely to succeed on a completely new host, in this case, on certain mosses.

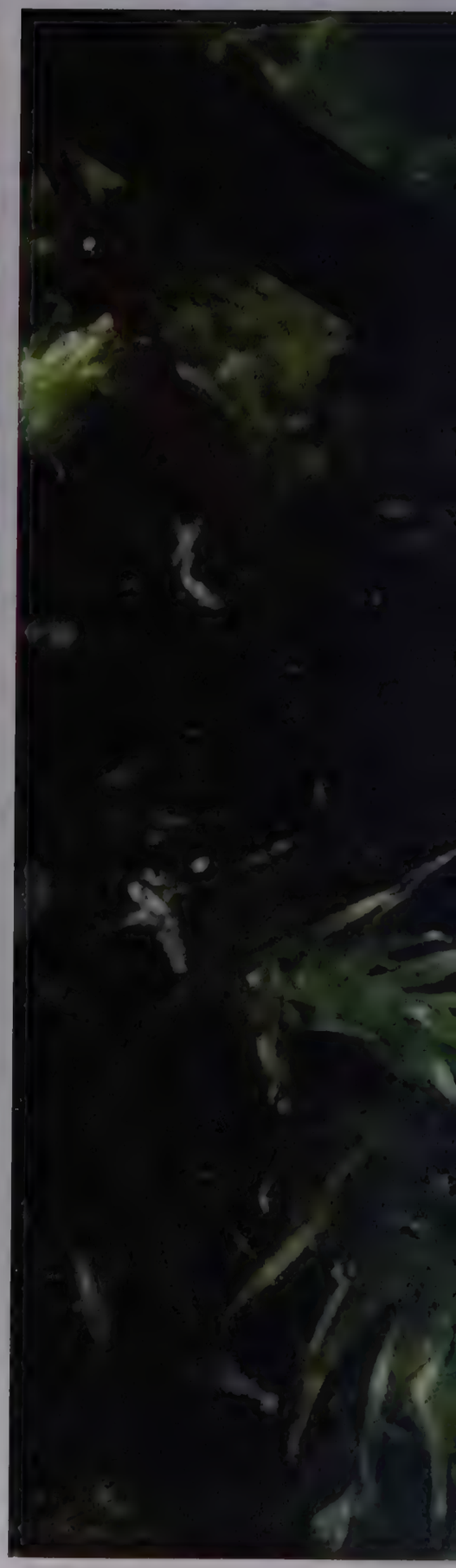
Although they are specialized, aphid life cycles involving alternate hosts are still capable of responding to changes in the abundance or desirability of one of the hosts. Some European relatives of the sumac gall aphid provide a dramatic example. Sumac once grew in Europe but disappeared from much of the continent as a result of the glaciations of the Ice Age between about 1.6 million to 12,000 years ago. Native European sumac is now restricted to the eastern Mediterranean region. In England and Scandinavia, however, a species of Melaphidina lives permanently on mosses. No migrants have ever been observed in these colonies. Apparently, the ancestors of these aphids managed to omit the sumac portion of their life cycle when the host plant was eliminated by the cold and ice.

Dwight Kuhn



In the long run, this solution may prove far from ideal, for the loss of the sumac phase of this aphid's life cycle also entailed the loss of sexual reproduction. A similar absence of sexual reproduction has been observed in other aphid species, including some important crop pests. In almost every case, the loss seems to be recent in origin; very few old lineages have completely given up sexual generation. This parallels the pattern found in animals generally: while permanently parthenogenetic lineages arise regularly in many groups, they do not persist.

The ephemerality of asexual species implies a strong advantage to sex, at least in the long term. What the nature of this advantage is remains one of the outstanding problems in evolutionary biology. But while the English moss aphids may have lived without sex for tens of thousands of years, probably they could not persist for millions. Their relatives in China and in Arizona's Catalina Mountains may have a longer future, despite the hazards of their annual sojourns. □



In September, the winged migrant forms of the aphid emerge from the protection of the gall, opposite page, through slits that have developed in its wall. One of these females, below, deposits her embryos on the moss that is the species' alternate home. Eventually, a new generation of winged females will arise, programmed to migrate back to sumacs.

Paul Mirocha

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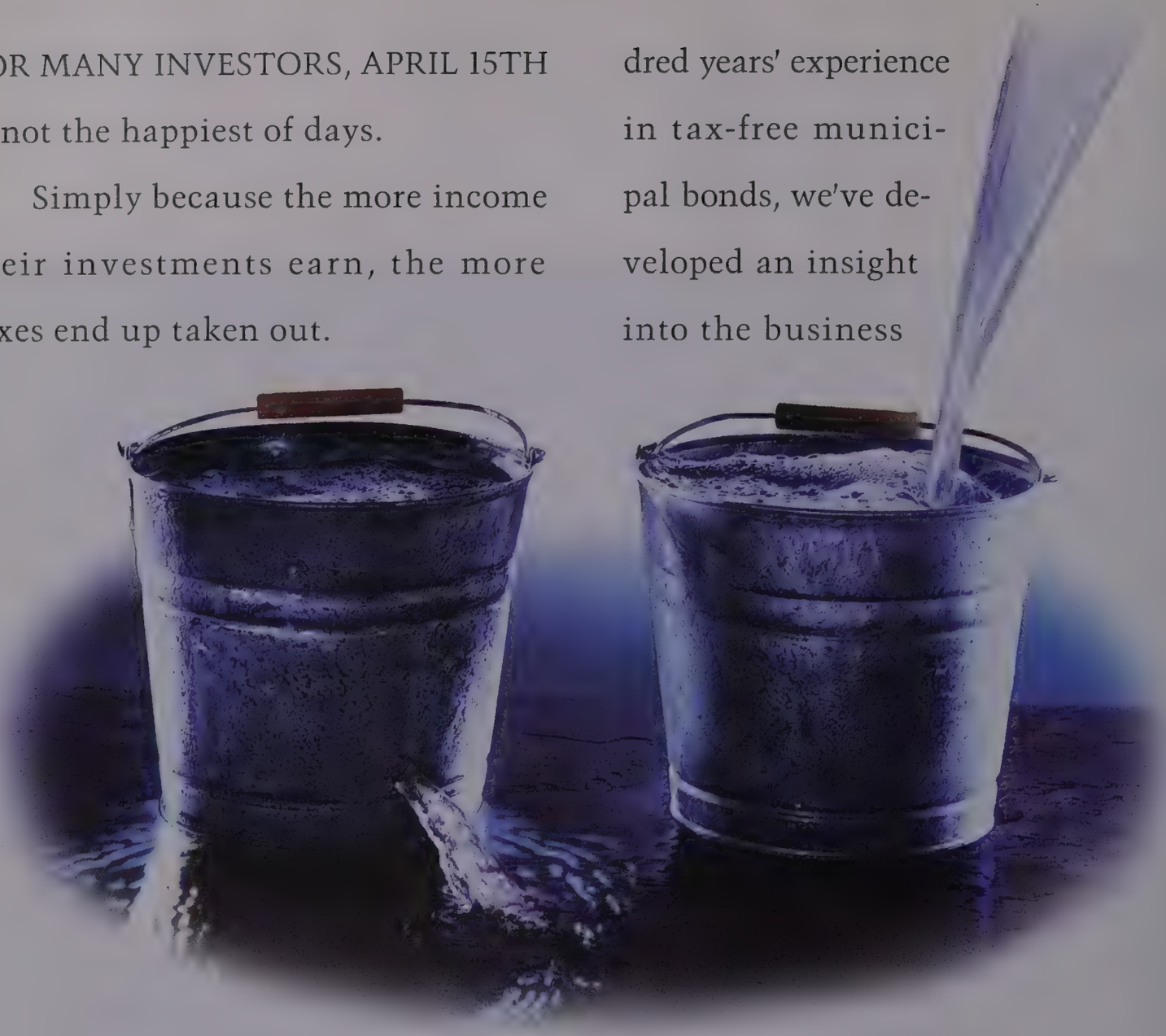

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Stilt Island, Lake Torrens, South Australia
Clive Minton

Sudden Life on Stilt Island

Rainfall in an arid land is a windfall for an Australian wading bird

by Keith Bellchambers and Graham Carpenter

Early in March of 1989, heavy rain fell across vast, arid stretches of inland South Australia. For the first time in some 100 years, 11,600-square-mile Lake Torrens, usually a bone-dry salt pan, filled with water. When such an event occurs, the lake is Australia's second largest. The water level ranged from an inch or two at its northern end to more than three feet in the south. The influx of fresh water stimulated long-dormant eggs of tiny crustaceans, such as brine shrimp, to hatch, grow, and reproduce. The lake became a highly nutritious saline "soup," attracting birds that quickly found out that Lake Torrens was a living lake once more.

About a month after Lake Torrens was resurrected, a huge breeding colony of banded stilts was discovered on small islands in the lake. With a total estimated population of 130,000 birds, banded stilts

are the most numerous wading birds native to Australia, yet no scientific sightings of nesting stilts were made until 1930. Since then, only about two dozen breeding sites have been found, most in scattered ephemeral lakes in remote and inaccessible parts of the outback. Although the birds are common much of the year along Australia's southern and southwestern coasts, until 1989 they had been observed breeding in inland South Australia only once before, in 1931. For ornithologists, the discovery of the Lake Torrens colony was the opportunity of a lifetime, allowing them to learn more about the species' breeding biology and behavior in a month than in the entire previous time the bird had been known to science.

When the rains began in 1989, Ian May, of the South Australian National Parks and Wildlife Service, started a systematic aerial search of inland saline lakes, hoping to make just such a find. In mid-April, after sixty hours in the air without a single sighting of a stilt, he came upon the 100,000-strong Lake Torrens colony. Two weeks later, we boarded a helicopter and were dropped off on the salty outskirts of the lake to observe and make the first detailed records of how banded stilts went about nesting and rearing their young.

Our first sight of the colony was breathtaking. As we circled over the largest of the three breeding islands, we saw that the nesting birds were tightly packed on several low dunes along one side of the island. From the air, the brooding birds—looking like black and white dots—contrasted vividly with the red sand on which they nested and the green of the sparse vegetation that grew nearby. Once on the ground, we set up our camp about 200 yards from the colony. The stilts gave constant, soft, yapping calls, while circling silver gulls squabbled and screeched, eager to make an easy meal of any untended egg or chick.

This bit of land, which we named Stilt Island, had been formed over many years as the precipitates of mineral-rich artesian groundwaters reached the surface and then hardened into a slab on the lake bed. Wind-driven sand built up on the south and west sides of this slab to form fringing two- to four-foot-high dunes. Sparse, salt-tolerant vegetation sprouted on these dunes, but the rest of the island was devoid of plants. The Stilt Island colony was located on and between the dunes. Because our attempts to enter the colony disrupted the brooding stilts and increased predation by the opportunistic gulls, we decided to retreat and study the colony through telescopes.

Keith Bellchambers and Graham Carpenter

Unlike other wading birds, banded stilts breed in dense colonies, placing their nest scrapes only about a foot apart, opposite page, bottom. The seclusion of an islet in the northern part of Lake Torrens, right, offers eggs and chicks protection from land-roving predators, such as foxes and dingoes.

Joe LeMonnier

We found that by the time of our arrival, breeding was already well advanced. About half of the estimated 100,000 birds Ian May had seen just two weeks earlier had left the island, along with their precocious chicks. However, May continued to conduct regular flights over the lake and soon discovered the beginnings of another colony on several islets sixty miles north, at the end of the lake. We rapidly broke camp and moved our field station there, hoping to observe breeding in this new colony from start to finish.

Two of the northern islands, each about twelve acres in area, were almost completely covered by new nests. In contrast to Stilt Island, these islands, characterized by stony expanses known as gibbers, supported a sparse, low saltbush shrubland. Various other wading birds, as well as terns, ducks, and swans, found the islands suitable for nesting, but they were greatly outnumbered by banded stilts. We estimated that about 50,000 stilts, or half the number that had been on the southern islands, were attempting to breed here. Again, predatory silver gulls patrolled the colony, so we opted to make most of our observations from an aluminum dinghy anchored some distance from the island. From there, we were able to witness the complete breeding cycle from courtship to egg hatch.

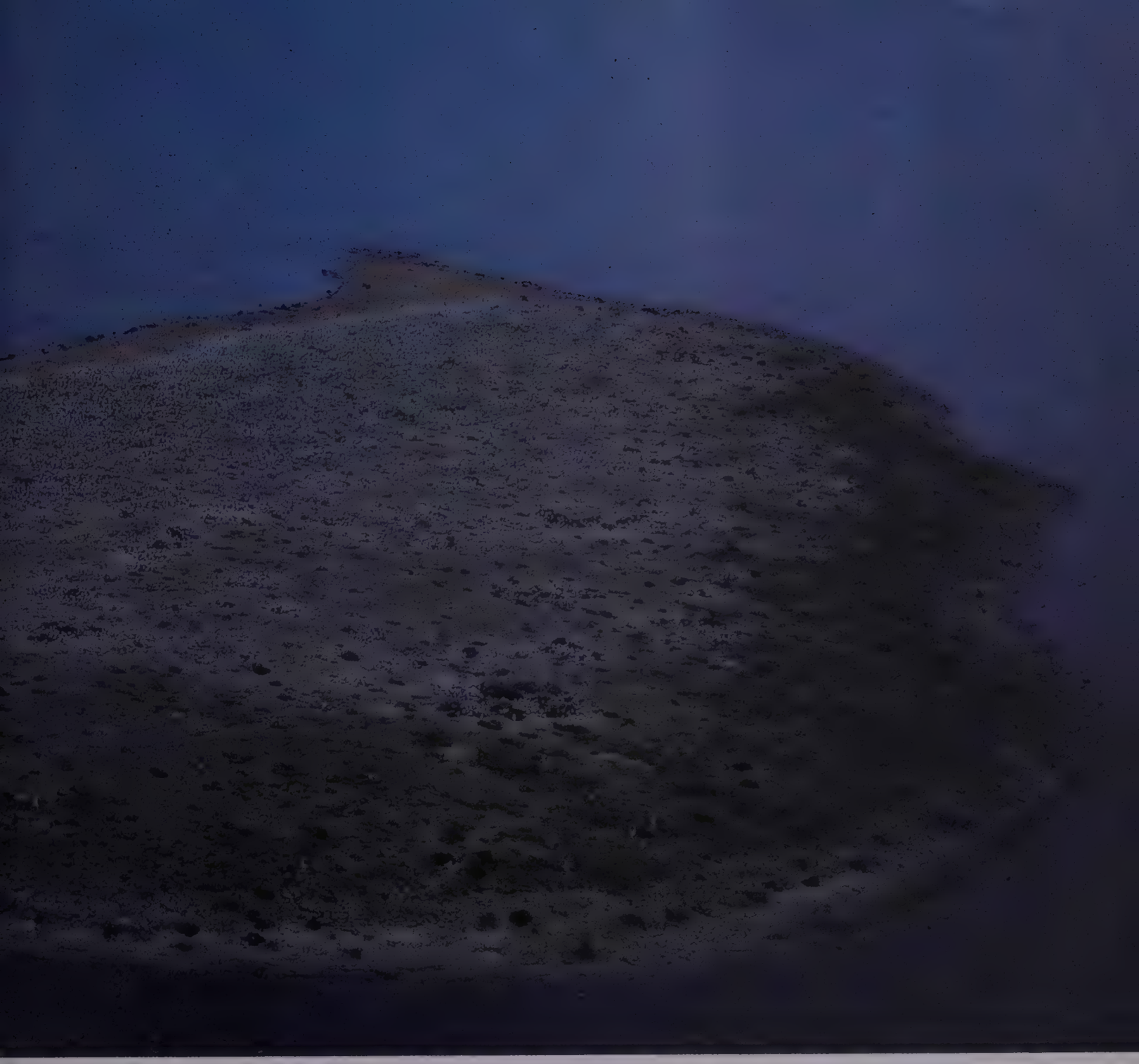
The differences between this northern colony and that on Stilt Island, separated by only a few weeks and sixty miles of water, were instructive and eventually gave us greater insight into the behavior and ecology of the bird, in particular the extreme efficiency of its breeding cycle.

Banded stilts probably do not nest annually but only when rainfall creates temporary inland saline lakes and encourages growth of their crustacean prey. Because of their irregular nesting schedule and their size—about sixteen inches tall—we suspect that banded stilts are relatively long-lived. In contrast to their closest Australian relatives, red-necked avocets and pied stilts, which nest in small, loose groups or in pairs, banded stilts breed in large, tightly packed colonies. These are usually located on islands or other isolated spots that afford some protection from ground-dwelling predators, such as dingoes, foxes, and feral cats.

To prepare its nest, a banded stilt makes a shallow scrape in the ground and sometimes lines it with a few dry twigs. Nests are spaced only about one foot apart, giving the birds just enough room to avoid constant bickering with brooding neighbors. Females usually lay a clutch of three or four eggs. Eggs vary between and within clutches in size, color (white to tan), and markings (blotches, swirls, and streaks). The eggs, similar in size to those of chickens, are relatively large for shorebirds, roughly 18 percent of the adult body weight of six to eight ounces.

Both clutch and egg size were smaller in the northern colony than on Stilt Island. Although we have no direct evidence, such as sightings of marked birds, we think that many of the birds breeding in this second colony may have been birds that had completed breeding earliest on the southern islands and that had enough time, energy, and confidence to renest. Our assumption is based purely on numbers. If 100,000 stilts nested in the south and another 50,000 in the north, this

Clive Minton



would exceed the total number of banded stilts in Australia. Some birds, therefore, must have nested twice.

During our many hours of nest watching, we occasionally witnessed one parent bird relieving another on the nest. Because the sexes are alike in size and color, we were not able to determine who was relieving whom. Most of these nest changeovers were confused affairs, with the relieving bird acting somewhat uncertain about taking over the nest duties. Our observations of individual nests, combined with the birds' behavior, led us to believe that banded stilts sit on the nest for extended periods, as they regularly took the time to stand and stretch their wings and legs and walked away from the nest briefly. This left the nest vulnerable to the depredations of silver gulls. We observed two main

Clive Minton

Chicks emerge after a brief twenty-one days in the egg, below. As soon as their white down dries and fluffs, they are ready to leave the nest scrape and head for food-rich water. They join stilts from other nests, right, before beginning the trek. Late nesters, right, below, are invariably harassed by silver gulls and usually lose all their young to these bold predators.

Clive Minton

methods of attack. Most gulls lurked among the brooding stilts, waiting for one to make a careless move; then rushed in and attacked the nest contents. Often the ensuing melee displaced other stilts brooding nearby, leaving more unguarded nests open to attack and resulting in a widening area of impact. Some gulls used a bolder tactic, pulling brooding adults off the nests and then raiding them.

The period from egg laying to hatching is about twenty-one days, a very short time for a bird of this size. But quick, efficient breeding is an evolutionary necessity for a species that nests on lakes that suddenly appear and just as suddenly dry up, taking away the food supply.

The chicks, too, mature rapidly. Unlike the cryptically colored young of all other shorebirds, banded stilt chicks are covered with pure white down. They have well-developed legs and are capable of extraordinary physical feats within a few hours of hatching. Adults never feed their chicks; the young begin feeding themselves as soon as they reach the water's edge after a trek from the nest. This may explain the large egg, its nutrients being needed to sustain the chick until it reaches food-rich water. Soon after the last chick emerges from the egg, the family abandons the nest scrape and heads to good feeding grounds. We noted that one adult, of unknown sex, guided each clutch of chicks. On leaving the nest, they sometimes joined other adults and chicks, presumably finding some safety in numbers. These groups were fluid, however, and tended to grow or shrink freely and frequently. Adults often attacked any strange chicks that blundered within their immediate reach.

On Stilt Island, the adults led their chicks across the barren limy slab—a distance of about 500 yards—before escorting them into the water and away from the island. We counted many thousands of chicks departing the islands on each of several days, most beginning their odyssey from midmorning to midday. All the while the adults maintained contact with their young with soft, clucking calls.

We tracked the birds that had left the nest on the northern islets from a light airplane and found them feeding in the northern part of the lake where brine shrimp were concentrated in only a few inches of water. Here the chicks grew rapidly and the adults replenished their strength. As soon as they reached water, chicks formed feeding "crèches" of up to several hundred birds. Accompanied by a few adults, the chicks worked their way across the shallows, their white downy bodies contrasting with the dirty brown water. From the air, crèches were visible over a huge expanse of the lake, their movements reflected in intricate patterns in the mud.

Crèching is an unusual behavior in shorebirds. In the case of banded stilts, it frees the majority of adults from parenting duties even before the young have fledged and gives them a chance to renest, should the usually short-lived lake water still be available. Precocial chicks, warm water, a relatively mild climate, and a vast and readily usable source of food may have fostered the development of crèching behavior in banded stilts.

At six weeks of age, the chicks were fully feathered, lacking only the chestnut breast band of the adults. Now capable of strong and sustained flight, these immature birds gathered in large flocks and

Keith Bellchambers and Graham Carpenter

often "buzzed" us in the dinghy as we went about our business on the lake.

Our observations suggest that banded stilts have much in common with other wading birds but also bear some striking similarities to flamingos, which are known in Australia only from fossil records. Like banded stilts, flamingos tend to nest on remote saline lakes when local conditions are favorable. Relatively large eggs, light-colored chicks, and the crèching of young birds are other traits banded stilts share with flamingos, but not with other waders. Our observations of ecological and behavioral similarities between these two species lend support to previous studies of their anatomy that suggest an ancient relationship between shorebirds and flamingos, via the banded stilt.

We found silver gulls to be main players

Clive Minton

On Stilt Island, below, adults shepherd chicks just a few hours old on a 500-yard, half-hour march to salty shallows, where they will feed for the first time. Right: Once in the water, the young form groups known as crèches and feed on tiny organisms, such as brine shrimp.

Keith Bellchambers and Graham Carpenter

in the life of the colony. The few historical accounts of nesting banded stilts mention predation of eggs and chicks by crows and ravens and birds of prey, but not by silver gulls, even when the gulls were nesting at the same site. In the Lake Torrens colonies, silver gulls ate eggs, newly hatched young, and downy chicks, and we estimated that they preyed on the contents of 60 percent of nests. Once away from the nest, chicks were relatively safe, although we did see some plucked out of the water as they swam. At a hatching weight of about one ounce, chicks are slightly more than a mouthful for a single gull, but after being torn apart by a squabbling gang of gulls, they are easily consumed.

While egg laying was largely synchronous throughout a colony, some birds were inevitably late in starting their nests. Early nesters avoided the heaviest predation by completing nesting and chick rearing before gulls flocked to the vicinity. These birds also renested if conditions remained favorable. Late nests were largely wiped out by silver gulls. In the past, flooding or, conversely, a drop in water level has caused colonies to be abandoned. Enormous numbers of flightless young can die if the waters in which they feed dry up. On Lake Torrens, gradually declining water levels prevented many stilts from renesting, but predation by gulls was the factor that prematurely ended the life of each colony.

In recent years, numbers of silver gulls in coastal Australia have grown, probably because of the availability of food at rubbish dumps. In very wet years, they move inland en masse to nest. The eggs and chicks of terns, plovers, cormorants, and ducks are among their victims. Banded stilts are at the mercy of these marauders, their defense being limited to covering the eggs or chicks and halfhearted pecking at attackers. This lack of retaliatory tactics suggests that high levels of gull predation are a new danger to banded stilts, something they have not had to cope with in the past and that they are not evolutionarily equipped to combat. This raises concerns for the future well-being of the species.

The 1989 flooding of Lake Torrens was a rare event, one that Australian banded stilts put to full advantage. It also opened an ornithological window, giving us a chance to document the successes of, and the new threats to, these birds on their largely secret breeding grounds. Although the scene at Lake Torrens may not be replayed for another hundred years, we hope to be able to add to our knowledge of the elusive stilts when other salt pans come to life. □

This shallow-water hermit crab is well defended by the sea anemones it carries on its snail shell.
S. Arthur Reed

A Shell with a New Twist

In the deep sea, anemones provide hermit crabs with a golden home

by Daphne Gail Fautin

In 1989, I arrived in Hawaii with hopes of observing two animals on the deep-sea floor, a golden-shelled hermit crab and the extraordinary sea anemone that rides on its back. I had seen this symbiotic pair languishing in aquariums, but now I had the opportunity to see them in their natural setting—a quarter mile below the ocean waves. I steamed southeast of Oahu on a ship operated by the Hawaii Undersea Research Laboratory, and when we reached a point above an undersea ledge, the ship's crew lowered the small submersible *Makali'i* into the water. Rough seas had given me a mild case of seasickness, but soon after the submersible was released from the ship and dropped beneath the heaving waves, I was fine.

The day before, the same rough seas had diminished my chances of spotting the anemone-toting crabs. All dive operations had been canceled, including plans to set out opened cans of cat food. The crabs, being supreme scavengers, would have gathered at the bait for my visit. Nevertheless, the pilot of the *Makali'i,* Bo Bartko, knew the area well, and if anyone could guide me to my quarry, he could.

When we reached 1,200 feet, the maximum safe depth for the craft, Bartko leveled off, and we cruised along a ledge of congealed lava. We were just inside the uppermost range of the deep-sea hermit crabs, animals that have been found at depths of half a mile. The darkness was pierced by brief bursts of light—colorful flashes emanating from sea fans and luminous jellyfish. Where the craft's floodlights illuminated a small patch of the rocky bottom, I scrutinized everything that came into view. After following the terrain for an hour, we finally spotted one of the spindly-legged hermit crabs, its golden shell concealed beneath an orangish pink anemone. It was ambling across the bottom, probably in search of its next meal. I couldn't learn much from that brief glimpse of the lone crab, but to me it was more exciting than the whitetip shark we saw circling the submersible two hours later as we waited for the mother ship to pluck us from the violent waves.

Ten years earlier, Hawaiian fishermen who had recently begun setting traps for

Lloyd Ullberg

Daphne Gail Fautin

deepwater prawns inadvertently captured hundreds of the anemone-toting crabs and brought them to the attention of Ann Fielding, a marine biologist at the Bishop Museum in Honolulu. She, in turn, contacted me at the California Academy of Sciences in San Francisco, where I was a curator in the Department of Invertebrate Zoology. Because of my special interest in anemones, she thought I might be able to identify this species attached to the thin golden shells of deep-sea crabs. Unable to give her an answer without seeing them, I asked if she could send me some specimens. They turned out to be among the most extraordinary examples of coevolution I had ever seen. But before explaining why, I should say something about the symbiotic relationship between anemones and hermit crabs.

Several dozen species of hermit crabs carry sea anemones on their shells, and marine biologists had assumed that the crabs use the anemones for protection. Donald M. Ross, a professor of zoology at the University of Alberta, tested the idea some twenty years ago. At the aquarium of the Stazione Zoologica, in Naples, he placed an octopus in a tank with shallow-water Mediterranean hermit crabs lacking anemones. The octopus easily pulled the crabs from their snail shells, devouring all six within a week. When he introduced an octopus to six crabs with anemones, however, none were harmed. In a typical encounter, the octopus reached out toward a crab with one arm, then extended another, then a third, but upon contact, the octopus abruptly withdrew its arms and tucked the other five under its body as it scuttled away in pain.

The anemone atop the crab had stung the octopus so badly that it would probably never touch another hermit crab. Like their cousins the jellyfish, sea anemones have tentacles that are studded with thousands of microscopic stinging capsules, or nematocysts, which fire hollow, harpoonlike threads that may inject toxin into an attacker's flesh.

Another series of experiments performed by Ross and Sigurd von Boletzky showed that, in the laboratory at least, hermit crabs carry anemones only when they are needed. Kept in predator-free tanks for months, crabs lightened their load by abandoning their anemones. If the researchers introduced an octopus into the tank, however, hermit crabs without anemones would attempt to steal them from crabs that had them, and crabs with only a few anemones on their backs would try to acquire more. In this game of "musical chairs," crabs unlucky enough to end up without at least one sea anemone were eaten, while the others were not. Ross and von Boletzky found that merely running water from a tank containing an octopus into one with hermit crabs caused the crabs to begin snatching anemones from one another. The chemical cues that warn of predators are usually present in the wild, so crabs in nature maintain this protective behavior.

Anemones deter other predators as well. Along the Atlantic and Gulf coasts of the United States, a species of box crab preys on hermit crabs using a claw that is specially adapted for snipping open snail shells. Richard Mariscal and Richard McLean, of Florida State University in Tallahassee, found that these predatory crabs killed about 80 percent of the hermit crabs that lacked anemones but less than 10 percent of those bearing anemones.

The anemones also benefit from the relationship. Most sea anemones seek a more or less permanent attachment on rocky areas of the sea floor where currents bring them the food they need. A hermit crab's shell provides the needed foothold and frees an anemone from its stationary existence. Mobility, in and of itself, is of no great benefit, but the crab takes its anemone to all the right places; crabs are excellent scavengers, sensing food at great distances and scurrying to it before other scavengers, such as sea urchins, isopods, or shrimp, can devour it. The anemone gets a free ride to the food, and as the

The golden "snail" shell, left, top, is really the work of a deep-sea anemone, Stylobates aeneus, *which expanded the original gastropod shell used by the hermit crab, visible at the center of the coil. Brought up from the depths off Hawaii, a deep-sea anemone, left, bottom, still envelops the shell it made for its crab partner. With its long, spindly legs, a deep-sea hermit crab, below, can move quickly across the ocean bottom.*

Alastair Birtles

crab tears away at its meal, the anemone feasts on scraps that drift about in the water.

This symbiotic relationship has drawbacks for both animals, however. If there were no need for protection, the crabs would be better off without the burden of their "machine gunners," as Randy Brooks, a zoologist at Florida Atlantic University, has called the anemones. He found that in addition to slowing the crabs down, carrying anemones is a balancing act. Brooks offered anemones of various sizes to hermit crabs with naked shells, and rather than placing them haphazardly on their backs, the crabs arranged them so that large anemones counterbalanced smaller ones.

The anemones run the risk of being abandoned by their partners when the crabs upgrade their homes. Because the hermit crab occupies a discarded snail shell, it must seek larger and larger shells as it matures. (If none are available, the crab stops growing.) Crabs of some species leave the anemones on the old shell, which may be found and occupied by another hermit crab moving up in the world. Other species of crabs have evolved behaviors that insure that the partners stay together. If I try to remove an anemone from a shell, I usually tear the anemone because of its firm attachment. But a crab that has just moved to a new shell gently rubs the anemone on the abandoned shell, and presto—the anemone releases its hold, and the crab transfers it to the new shell, where it attaches firmly. More remarkably, some anemones initiate the move. With its base still attached to the old shell, the anemone bends over so that its tentacles adhere to the new one. It then releases its base, somersaults, and attaches to the new shell.

When I examined the anemones adorning the deep-sea hermit crabs from Hawaii, I realized they were very different from anemones that ride shallow-water crabs, and that they had achieved an elegant solution to the problems arising from the crabs' need for ever larger shells.

In the deep-sea species, only one anemone is found with each crab, its base wrapped entirely around the shell. And rather than perching on top with its mouth pointed upward, its body is slung beneath the shell so that its mouth opens behind that of its hermit partner (the better to share its meal). Most hermit crab anemones are robust, but these are very delicate. The laboratory specimens that I examined had been shrunk by the preservative, causing their bases to pull back and reveal a glistening gold shell that was so thin it felt like parchment and could be dented like a Ping-Pong ball. When I removed the shell from the fluid preservative, its shiny gold dried to a chalky white. I came to the startling conclusion that the anemone had fabricated the hermit crab's "snail" shell.

I had never heard of such a thing. Nor had my good friend and mentor Cadet Hand, a professor emeritus at the University of California at Berkeley and an expert on sea anemones and their symbionts. But after searching through a number of scientific volumes, I found that my "discovery" had been made twice before. In 1903, the famous American malacologist William Healy Dall described a new spe-

James Carmichael; NHPA

The whelk shell of a shallow-water hermit crab, below, is loaded down with anemones. Right: A species of anemone not usually associated with hermit crabs has settled on a shell and may offer the crab some protection.

Heather Angel

cies of snail from deep waters near Hawaii. He named it *Stylobates aeneus*—the brassy walker on stilts. Dall did not actually see the snail; his description was based on its shell, which was occupied by a hermit crab and topped by a sea anemone, both of which he discarded as uninteresting to a malacologist. Several years later, he published a short note revealing rather sheepishly his conclusion that the shell was made by the sea anemone on it, and therefore the name *Stylobates aeneus* rightly belonged to the anemone. Published in a journal of malacology, this startling emendation escaped notice by students of anemones.

In 1928, the most prolific sea anemone taxonomist of all time, Oskar Carlgren, then of Lund University in Sweden, published a 144-page list of the sea anemones collected by the German Deep-Sea Expedition, one of several expeditions launched about the turn of the century to explore the ocean depths by trawling and sampling the bottom. (These efforts, which emulated the British *Challenger* expedition of the mid-1870s, created the foundations for many of the world's best marine zoology collections.) Buried amid accounts of thirty-one new species was the description of *Isadamsia cancrisocia,* an anemone that makes a shell in which a hermit crab lives (hence the species name meaning "associated with a crab"). To Carlgren, an anemone that made a shell that looked precisely like one made by a snail was apparently unremarkable—sea anemones, after all, live at all depths and latitudes, form symbioses with algae and fish, not to mention crabs, and are, all in all, extraordinary beasts.

After examining the original anemones Carlgren had studied, and hundreds more from Hawaii and Guam, I concluded that they belong to two species in one genus. *Stylobates aeneus* is found throughout the mid-Pacific, and Carlgren's species, now properly termed *Stylobates cancrisocia,* is known only from the German Deep-Sea Expedition specimens, taken in the Pemba Channel, between Pemba Island (near Zanzibar) and the coast of East Africa. Since rediscovering these creatures, I have described a third species of shell-making sea anemone from the coastal waters of Western Australia and am studying specimens of other new species from the Coral Sea and the Gulf of Mexico. Although some of the "snail" shells produced by these anemones are far from perfect replicas, they are all made of the same brassy, parchmentlike material. Each anemone is oriented somewhat differently on its shell, and each associates with a different hermit crab species.

With the help of Martin Liberman, a chemist in San Francisco, I determined that the organic material of the shell is largely chitin, the substance of which crab shells and insect cuticles are made. *Stylobates* is not the only anemone capable of producing chitin. In one genus, an anemone uses chitinous material to construct a spongy float, from which it dangles, bobbing on the waves. An anemone of one shallow-water European species can add small amounts of the material to a hermit crab snail shell, enlarging it so that the crab does not have to change homes frequently. Only *Stylobates,* however, can build entire shells. The anemone begins the process by attaching itself to a hollow object (usually a shell from a small snail or other mollusk) into which a tiny hermit crab has inserted its abdomen. The anemone coats the object with the chitinous material and then extends the coating as the crab grows. Because the hermit crab's body is curved to fit into coiled snail shells, the anemone's secretions—guided by the corkscrew shape of the hermit crab's abdomen—produce a replica of a snail shell, no matter what the shape of the object originally inhabited by the hermit crab. The anemone produces the structure while perched on the crab, whereas the snail constructs it from within. Thus, through the coevolution of three unrelated creatures, the spiral shape of the snail is replicated by the hermit crab's abdomen and then the anemone's shell.

In the deep sea, the symbiotic relationship is more than advantageous; it is essential to the survival of both crab and anemone. By producing shells for the hermit crabs, the anemones can live where the bottom is muddy or sandy, with no place for firm attachment. And the deep-sea hermits, which are among the largest of their kind, need not expend energy finding larger homes as they grow. (There are not many large snails in the deep sea, where food is notoriously scarce.) Moreover, calcium carbonate, of which snail shells are made, dissolves easily in the water of the ocean depths, so even if snails were plentiful, their shells would not last as long as they would in shallow water. In the deep sea, the anemones' "fake" shells are better than the real thing.

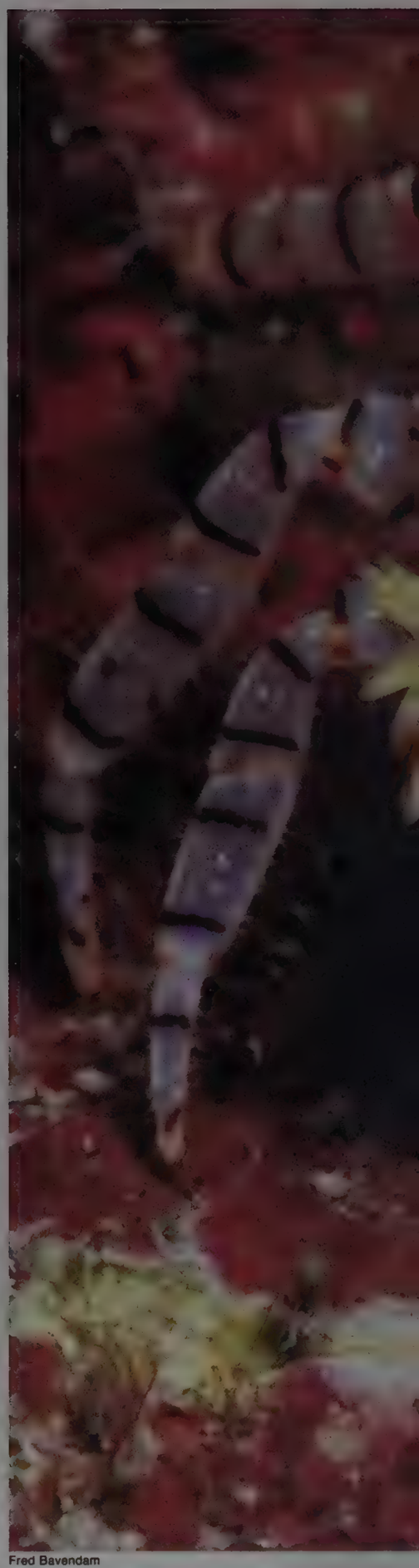
Crawl like a Crab, Sting like an Anemone

Hermit crabs are not the only crabs to take advantage of an anemone's protective sting. By using small anemones like boxing gloves, boxer crabs ward off attackers. In this way, anemone-bearing female boxers can guard not only themselves but also the tiny red eggs carried under their abdomen, right. Also known as the pom-pom crab, this species is found in shallow tropical seas, mainly around Indonesia.

In the early 1900s, these animals aroused the curiosity of James E. Duerden, a professor of zoology at Rhodes University College, in what is now South Africa. To see how anemones are recruited, he removed them from a boxer crab in his aquarium and found that the crab ignored the anemones until it bumped into one. Upon contact, however, the crab would pry an anemone loose with a front leg and grasp it with one of two small, slender claws used only to carry anemones. Since damaged anemones quickly regenerate, Duerden reasoned that a crab might rip an anemone in half, producing one for each claw. When threatened, an anemone-toting crab thrusts the anemones in the direction of the attacker, stinging it upon contact. Rather than immediately retreating as most crabs do, the boxer crab, Duerden found, instinctively strikes out even when its slender claws are not armed with anemones.

Porcelain crabs, below, also benefit from anemones; they are closely related to hermit crabs but resemble true crabs in shape. These small, flat crabs live their entire lives on and around giant sea anemones. They often share their homes with clownfishes, which also live under the anemones' protective shield, rarely venturing more than a few feet from them. Like the fish, porcelain crabs live in groups and remain safe from predation as they move among the anemones' tentacles, which are deadly to other crabs their size. Why they are immune and what, if anything, anemones receive in return remain mysteries.—*D. G. F.*

Burt Jones and Maurine Shimlock



Fred Bavendam

Morman Branch, Florida

by Robert H. Mohlenbrock

In the Big Scrub of central Florida, ancient accumulations of windblown sand provide a foothold for scraggly pines, turkey-foot oaks, and palmettos, as well as a number of unique plant species. Several threatened species of animals live there, too; among them, the Florida scrub jay, the sand skink, and the blue-tail mole skink. Within this generally dry region, a 620-acre swamp and a 2-mile-long streamlet known as Morman Branch provide an oasis of moist habitat. Steve Orzell, a former student of mine who is now an ecologist with the Florida Heritage Program, invited me to visit the area, which lies in the Ocala National Forest.

We trudged in on a Forest Service "road" consisting of deep sand not negotiable by ordinary vehicles. For half a mile, our route wound through scrubby trees; except for lichens, vegetation on the forest floor was sparse, exposing large patches of bare sand. Soon we reached Morman Branch, whose cool, flowing water was so clear that we could easily see the rippled, sandy bottom. The narrow stream, a tributary of Juniper Creek, passes through a swamp that occupies a barely perceptible depression. The swamp is fed by small springs and seepages created by rainwater as it percolates through the surrounding sand hills.

The soil is always moist in the swamp and along the stretch of Morman Branch that leads to Juniper Creek. Botanists Dan Ward and Andre Clewell credit this to the even flow of spring-fed waters throughout the year. Among the plants growing in Morman Branch is sago pondweed, a flowering plant that cannot tolerate any degree of desiccation. Other aquatic species are pickerel weed, eelgrass, and coontail.

While most of the swampy habitat is heavily wooded with black gum, red maple, loblolly bay, and sweet bay magnolia, the occasional openings are dense with grassy vegetation—and poisonous cottonmouths. Each opening has a shallow channel of flowing water supplied by numerous springs. Many plant species rare in this part of Florida turn up here, including Chapman's sedge and the large-flowered grass-of-Parnassus. In the muck grows flaccid quillwort. A distant relative of ferns, this uncommon quillwort produces reproductive spores at the bases of its spreading, grasslike leaves.

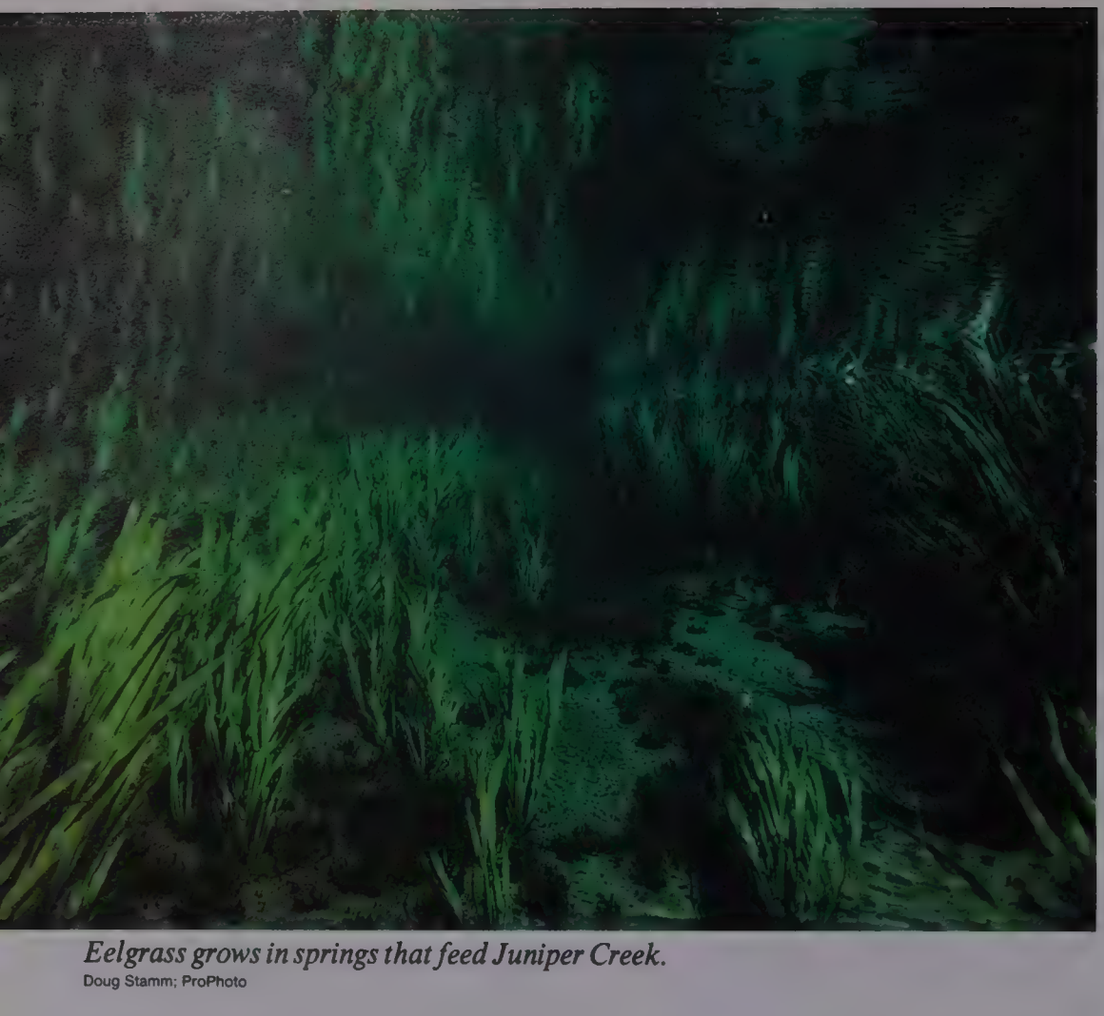
Scattered along the stream and particularly through the swamp forest are Atlantic white cedars, cone-bearing evergreens more common farther north, on the Atlantic Coastal Plain. A rare species that grows with the white cedars is the shrubby star anise, a relative of magnolias. Its inch-wide pale flowers give rise to ribbed, several-pointed, anise-scented fruits. Another unusual plant is climbing pieris, a vine that climbs almost exclusively on Atlantic white cedars or pond cypresses (most vines are less particular, growing on whatever host is nearby).

Climbing pieris is one of the few vines in the heath family, which consists mostly of shrubs or small trees, including rhododendrons, azaleas, mountain laurels, blueberries, and cranberries. The vine grows just inside the bark of the white cedar or other host tree, periodically breaking through with short branches that bear clusters of leathery, evergreen leaves and elongated sprays of small white flowers. With age, these branches die and break off, to be replaced by new branches higher up on the host. Ward and Clewell have observed one branch of climbing pieris forty feet above the ground. As the bark on the lower parts of the white cedar trunk ages and begins to flake off, the reddish stems of the vine are often revealed.

The stand of Atlantic white cedars that grows along Morman Branch and in the swamp is the world's southernmost, one of two very isolated colonies in peninsular Florida. The species' main range extends

The Florida scrub jay, above, lives in dry, sandy areas. Vines of climbing pieris, opposite page, ascend a white cedar trunk covered with mosses and lichens.

Kevin Barry (above) David and Hayes Norris (opposite page)



Eelgrass grows in springs that feed Juniper Creek.
Doug Stamm; ProPhoto

from New Jersey to South Carolina, with isolated stands in southwestern Georgia, the Florida panhandle, southern Alabama, and southeastern Mississippi.

The more northerly stands of white cedars are often nearly pure groves of uniform age. They probably arose when seedlings germinated en masse after a previous forest was logged or destroyed by fire. Their growth rings are usually all about the same width, indicating a fairly uniform rate of growth. In contrast, Ward and Clewell have found that the Ocala stand is not of uniform age and that the cedars are mixed with several other woody species. In addition, the annual rings show that the growth of these trees was suppressed when they were young, generally for several decades.

These telltale features suggest that the white cedars we see today have filled in gaps created haphazardly in the forest. When a large tree dies or a large branch falls, more light reaches the forest floor, stimulating the germination of numerous white cedar seeds that lie dormant in the soil. Before the seedlings are very old, however, the canopy may close over, causing them to perish. But a new gap may allow some to survive and grow into small trees hardy enough to tolerate periods of low light. Eventually, a few trees reach the canopy, where their growth rate accelerates. Finally, they produce seeds that perpetuate the cycle.

White cedars are able to outdistance all other trees in the canopy because of their resistance to disease and decay. With time, they tower well above other species, becoming a target for lightning strikes, the only natural danger that threatens them. Fire has not played a major role in the Ocala stand, as is evident from the staggered ages of the white cedars. When they occur in this habitat, fires are dampened by the wet soil and by the foliage of mixed broad-leaved hardwood trees and herbaceous undergrowth.

Ward and Clewell have studied environmental conditions along Morman Branch to try to discover why white cedars grow here and not in other, similar-looking wetlands in nearby parts of peninsular Florida. One reason may be that even though they grow in a wet environment, white cedars cannot tolerate flooding; consequently, they do not live in the floodplains of Florida's large rivers, where water levels fluctuate drastically with the seasons. And because of their shallow roots, the trees may be harmed by the deposition of sediments.

Botanists are not the only forest visitors to pay attention to the white cedars. Male Florida black bears mark tree trunks to warn off other bears. The largest white cedar in the stand has been ripped and shredded to a height of six feet by their claws, and coarse black hairs are embedded in resin droplets that exude from the scrapes. The layers of scar tissue on the trunk show that this tree has been a territorial marker for several generations of bears.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.

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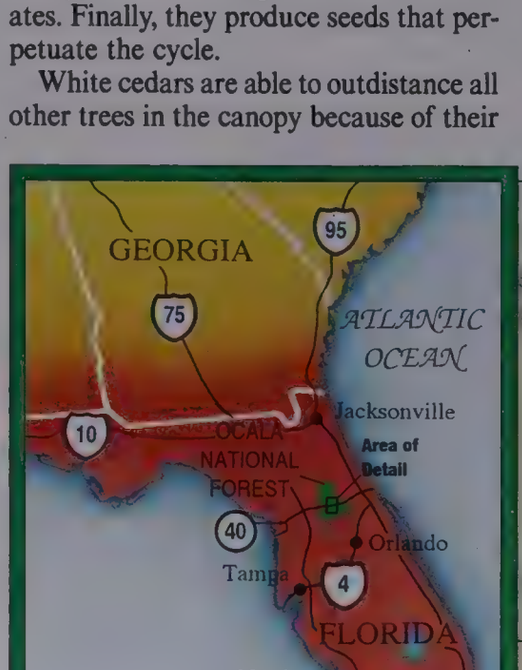

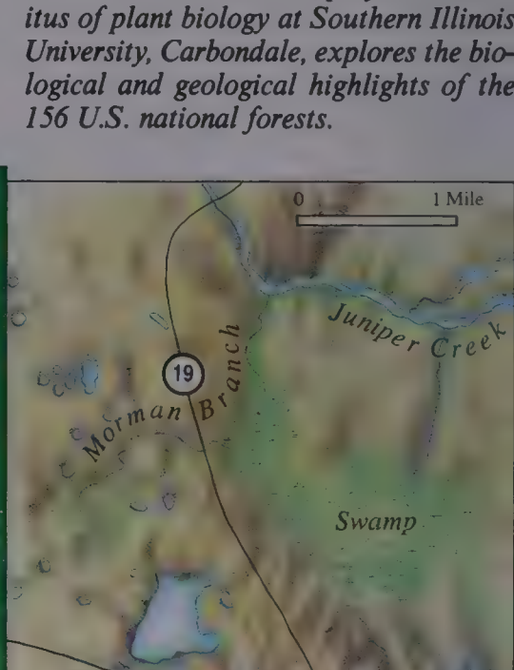

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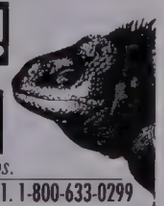

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Full-Moon Feasts

by Gail S. Cleere

Easter falls on April 19 this year. The holiday has no fixed date, and its occurrence has thus been a source of confusion through much of history. Easter Sunday is the Christian holy day that celebrates the resurrection of Christ, an event believed to have occurred during the Jewish spring feast of Passover, the timing of which depends on the phase of the moon. Because the date of Passover varies, so does the date of Easter, although a different set of rules determines Easter. In the fourth century A.D., the First Council of Nicaea established rules for fixing the date of the holiday. But the timing remained a problem until the sixteenth century, when Pope Gregory XIII finally settled it: Easter would fall on the Sunday following the ecclesiastical full moon that occurs on or after the vernal equinox, defined as March 21. Easter's date is then used to determine the dates of many other Christian feast days throughout the year.

According to the eighth-century English historian the Venerable Bede, the name "Easter" derived from a pagan goddess, Eostra, deity of dawn and the spring. Many of Easter's popular folk customs persist from pagan times, but with a Christian patina. The traditional Easter sunrise service may stem from the ancient practice of going to some high hill to watch the sun rise about the time of the equinox. The secular Easter bunny in all probability comes from the medieval "hare hunts" that took place on Easter Monday or from the later custom of eating hare pies at Easter. But it is the Easter egg, classic feast day food and focus of Easter games, that endures and is most familiar. Universally recognized as a symbol of life and spring reawakening, eggs have been rolled, hunted, painted, and dyed for centuries.

April Fools' Day

Astronomy pops up in the oddest places. Take April Fools' Day for instance. While its origins are obscure, some claim that this day, set aside for foolishness and pranks, has to do with the fickleness of the weather, which does not always follow the changing of the seasons. The Greek version is embodied in the spring versus winter story of Demeter, the Greek goddess of fertility. Bereaved by the abduction of her daughter by Pluto, king of the underworld, Demeter punished the earth by withholding her bounty. Later, when Pluto agreed to allow her daughter to return for six months each year, Demeter made the earth fruitful again. Both the Greek legend and the Roman feast day of Cerealia (Ceres was the Roman name for Demeter) have something to do with the proximity of the vernal equinox (March 20 or 21)—the first day of spring. Is it foolish to look for warm weather this time of year?

The Planets in April

Mercury is not easily visible for observers in the Northern Hemisphere in April and May. At its best on the 23d, it is only five to seven degrees above the eastern horizon at sunrise.

Venus hovers just above the horizon to the east, half an hour or so before sunrise. Despite its brilliant −3.9 magnitude, the planet is soon obscured by the solar glare.

Mars rises about one and a half hours before the sun all month, sandwiched between Mercury and Venus to its left, close to the eastern horizon, and Saturn, Uranus, and Neptune to its right, somewhat higher in the southeast. This month ruddy Mars resides among the faint stars of Aquarius.

Jupiter, in Leo below the belly of the lion, is just to the east of the bright star Regulus. High in the southeast after sunset, having risen in midafternoon, it remains the lone planet in spring's early evening skies, setting just before the onset of morning twilight. On the 13th, Jupiter is six degrees above the waxing moon.

Saturn is in Capricornus, in the southeastern sky just before sunrise. Look for this ringed planet shining at +0.8 magnitude amid stars that are 3d magnitude or fainter. (Contrary to what one might expect, the greater the magnitude numerically, the fainter the star or planet.) Saturn's closest stellar neighbor this month, just left of the planet, is Deneb Algedi, which means "tail of the goat." Look for Saturn on the 25th and 26th below the waning crescent moon.

Uranus and **Neptune** are west of Saturn in the morning sky, in the summer constellation Sagittarius. About an hour before sunrise, look due south for this teapot-shaped constellation. These dim planets can be found with the aid of special star maps published in popular astronomy magazines.

The **Moon** is new on the 3d at 12:01 A.M., EST; reaches first quarter on the 10th at 6:06 A.M., EDT; is full on the 17th at 12:42 A.M., EDT; and reaches last quarter on the 24th at 5:40 P.M., EDT.

The Lyrid meteor shower peaks on the night of the 21st/22d, but the moon rises about midnight and will largely obscure the meteors. Chinese accounts of the Lyrids date back to 687 B.C., making this the first recorded meteor shower.

Gail S. Cleere writes on popular astronomy and is a founding member of the International Dark Sky Association, an organization dedicated to preserving the skies for astronomy.

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Romancing the Blackfeet

by Hugh A. Dempsey

In the late nineteenth century, people's romantic ideas about the Wild West focused on explorers like Lewis and Clark, Indian wars, gunfighters, and Texas cattle drives. But as the West became more settled by the turn of the century, the nation began to discover the rich heritage of its original inhabitants, the Native Americans. Confined to reservations and fast disappearing through disease and neglect, they seemed to typify the freedom and grandeur that had once been part of the western mystique.

BLACKFEET AND BUFFALO: MEMORIES OF LIFE AMONG THE INDIANS, by James Willard Schultz (Apikuni). *University of Oklahoma Press, $12.95; 384 pp.* BLACKFOOT LODGE TALES: THE STORY OF A PRAIRIE PEOPLE, by George Bird Grinnell. *Bison Books/University of Nebraska Press, $7.95; 311 pp.* OLD INDIAN TRAILS, by Walter McClintock. *Houghton Mifflin Co., $10.95; 400 pp., illus.*

Books on the Blackfoot Indians of northern Montana and southern Alberta were among those that gained instant popularity during this period. The public seemed to have an insatiable appetite for stories about the people they had dispossessed, supplanted, and almost annihilated. Some of this interest was academic, as evidenced by the work of anthropologist Clark Wissler, who produced six important monographs on the Blackfeet for the American Museum of Natural History between 1908 and 1918. During the same period, ethnolinguist Christian C. Uhlenbeck undertook major Blackfoot language studies, the first being published in the Netherlands in 1911.

But the people who reached the broadest audiences and brought the Blackfeet to international prominence were those who wrote in a popular vein. And leading this parade were three men who had lived and traveled with the Blackfeet—James Willard Schultz, George Bird Grinnell, and Walter McClintock. Their books presented the Blackfeet as real people with whom the public could identify. Today, each of these authors has one or more works in print.

Like many North Americans, my first exposure to the Blackfeet in literature was through the writings of James Willard Schultz, a man who in the 1870s and 1880s had lived with the Piegans (one of the three tribes of the Blackfoot nation). At the time, I was living in Edmonton, Alberta, and dating the Blackfoot girl I later married (we've now been married for thirty-nine years). She was from another Blackfoot tribe, the Blood, so I already had some knowledge of the people. Yet when I read Schultz's classic *My Life as an Indian,* I was captivated by his romantic view of the idyllic life Native Americans had led before they were forced to settle on reservations. Only later did I discover that Schultz was simply a storyteller, and that what he created best was atmosphere, not history.

In my view, Schultz wrote only two works of nonfiction—*Signposts of Adventure* and, with Jessie Donaldson, *The Sun God's Children. My Life as an Indian* and its companion piece, *Friends of My Life as an Indian,* are really in the realm of semifiction. His more than thirty other books are purely fiction, even though they may be loosely based on historical fact.

But what fiction! Writing primarily for young boys, Schultz had the ability to bring Indian life into the hearts and imaginations of his readers. Often the hero was a young Blackfoot or white boy with whom the readers could immediately identify. When the hero was rescuing a stolen horse or galloping wildly in pursuit of a stampeding buffalo herd, the readers were right there with him.

Since Schultz's death in 1947, several books have been published that bring together the many stories he wrote for boys' magazines, newspapers, and other publications. They are vintage Schultz, filled with all the romance and adventure of his earlier books. *Blackfeet and Buffalo,* a recent reprint, ranges from buffalo hunting to exploring with George Bird Grinnell in what is now Glacier National Park.

Like Schultz's other books, it is a curious mixture of fact, fiction, and semifiction, all seemingly presented as true. The author's accounts of his work with Grinnell in establishing Glacier National Park and naming landmarks within it are probably factual. But his other "autobiographical" accounts are suspect; they are exciting to read but are so dramatized that one must approach them with caution.

For example, Schultz claims he was shot in the arm when he was with a Piegan war party that killed an Assiniboine named White Dog. This story was reprinted from a 1939 account Schultz wrote for a newspaper in Great Falls, Montana. Yet, in his first version of the tale, related in 1923, he was merely a clerk at a trading post that supplied ammunition to the Piegans. Only later did Schultz insert himself into the tale as a principal participant. This is typical of Schultz's writings—highly entertaining but factually suspect.

It was his introduction to Schultz that led Grinnell into a serious study of the Blackfoot tribe. The two men met in the 1880s when Grinnell, as editor of *Forest and Stream* magazine, began to publish some of Schultz's stories. Grinnell tried to encourage the young man to write a book about the Blackfeet, but when Schultz demurred, Grinnell launched his own study. In 1892, after several trips to the Blackfeet Indian Reservation and to Glacier National Park, Grinnell published his classic work, *Blackfoot Lodge Tales.*

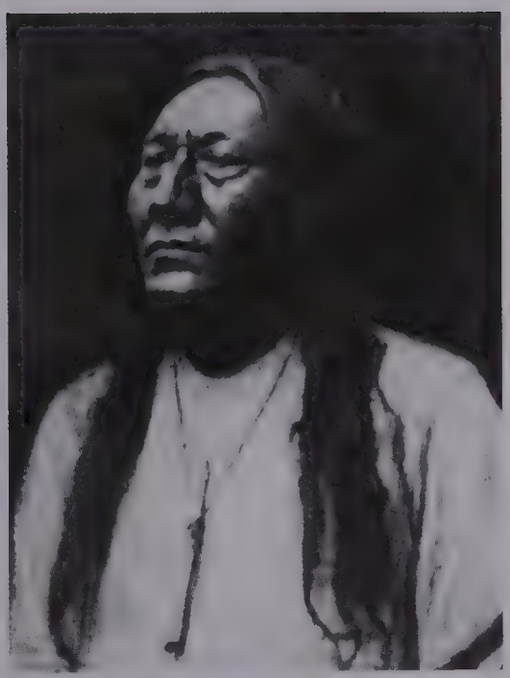
Unlike Schultz's folksy stories, Grin-

nell's work is a solid yet readable study of the Blackfoot people. It is filled with adventure stories and legends as told by the Indians themselves and concludes with an examination of the social life and customs of the tribes. While Schultz's work is somewhat dated, both in style and in content, Grinnell's book has stood the test of time as an important contribution to the history and ethnography of the Blackfeet. It has been reprinted steadily over the years as the demand for it has remained constant. It is also a book that for the past eleven years I have had on a recommended reading list for my ethnohistory students at the University of Calgary. For some of my Native American students, reading *Blackfoot Lodge Tales* has been a voyage of discovery into their own culture.

Walter McClintock stands about midway between Schultz and Grinnell in his treatment of the Blackfeet. He first visited the reservation in 1896, when he was part of a government expedition recommending a national policy for the United States Forest Reserves (which later became the Forest Service). He established close relations with the Piegan leader Mad Wolf and was adopted as his son. During the next fifteen years, McClintock made many trips to the reservation. And in 1905, he made a memorable journey with Mad Wolf to visit the Bloods and North Piegans on their reserves in Canada.

McClintock's first book, *The Old North Trail,* was published in England in 1910. Thirteen years later he rewrote the entire volume for an American edition entitled *Old Indian Trails.* In later years he also produced numerous monographs, particularly for the Southwest Museum in Los Angeles, but all have been virtual rehashes of his original volume.

McClintock's *Old Indian Trails* is an intriguing and sometimes overwhelming mixture of stories, legends, and descriptions of religious rituals, all woven into his



Chief Mad Wolf
Walter McClintock

own personal account of his life with the Blackfeet. He tells of being inducted into the tribe, participating in ceremonies, and living with his adoptive family—almost a nonfiction version of some of Schultz's stories, but lacking their excitement and vitality. At other times McClintock takes a serious anthropological approach as he describes the social customs of the tribe, including many of their songs, and catalogs the names, uses, and preparations of various herbs and medicinal plants.

In spite of their importance and interest, McClintock's books have not fared as well as those of Schultz and Grinnell. Seldom reprinted, they have been unavailable to most people, except for those who can visit special collections in libraries.

This is a shame, for *Old Indian Trails* has much more personal detail about Blackfoot daily life than can be found in any other sources from that period. Yet the future of McClintock's works may depend more on Native American concerns than on the size of the market. Since the revival of interest in their own culture, which began in the late 1960s, the Blackfeet have become more and more sensitive about such topics as native religion. Their demand for the return of medicine bundles from museums, their practice of applying religious taboos to things that were secular a few years ago, and a general feeling that the white man has "ripped off" their culture have made the study of Native American life an area to approach with caution, understanding, and diplomacy. Today, many Blackfeet are tired of being "studied," whether by social scientists or century-old authors. For this reason, McClintock's detailed descriptions of medicine pipe ceremonies and other sacred rituals in a book designed for broad public appeal might be the basis for some consternation.

This problem should not exist for Schultz's works, which are simply pleasant stories that consistently feature the Blackfeet as heroes. Nor is Grinnell's work likely to suffer, because of his factual and almost academic approach.

Yet the works of all three authors are important—Schultz's for entertainment, Grinnell's for knowledge, and McClintock's for his descriptions of daily life. Any or all may face some passing criticism from the Native American community, but I'm convinced that they will stand the test of time because they were written when the Blackfeet were barely into their first generation of reservation life. That in itself makes them important. Besides, they are a good read.

Hugh A. Dempsey is chief curator emeritus of the Glenbow Museum in Calgary, Canada, and the author of many books on the Blackfoot Indians. He expects his latest work, The Reincarnation of Low Horn and Other Blackfoot Tales, *to be published soon.*

Dueling Proverbs

Can a young dog learn old tricks?

by Roger L. Welsch

My father is German, and he does some German things, and I can say so, because I'm a German. So don't send me letters about how the Germans invented cream-filled pastries, designed the first autobahn, and used to have great singing contests. I know all that. Being German, my father speaks in proverbs. To him, proverbs are little nuggets of traditional wisdom that speak to every issue and question. "Why can't I have a car of my own?" I would ask, and Dad would answer, "The apple doesn't fall far from the tree."

"Huh?" I would say.

Or maybe he would tell me to mow the lawn and I would explain that I couldn't because . . . because . . . because I had to study for a woodworking shop exam the next day. He would say, "Strain at a gnat and swallow a camel." I would say, "Huh?" And he would say, "Mow the lawn." And I would think, "Germans!"

Now that I think of it, that was the reasonable side of Dad. If I took a stand and clearly had logic, justice, and maybe Mom on my side, he would, without a pause, say something like, "Augenflaugen bracht magen Platz."

"What does that mean, Dad?" I'd ask, even though I knew better.

Roger, Chris, and Bertha Welsch, circa 1942

"That means, 'Don't slander your neighbor until you have walked six miles in his moccasins.' "

"After that it's okay to slander him?" I asked, realizing at once that I would have done better by asking him which of those words was German for "moccasins."

"Flanzen bogen distel sichen Universitaet—Honor thy father or lose driving privileges until you graduate from college," he explained.

When I did go off to college, one of the first things I did was take a course in German to see if Dad was really speaking German. As it turned out, he was, sort of. But the real advantage of what eventually became my graduate degree in German was that I came to understand his proverbs and learned enough more, thanks to his tuition payments, to argue effectively with him, using an arsenal of my own proverbs.

In graduate folklore school at Indiana University I learned that in many cultures, proverbs are correctly considered to be collective wisdom and can be introduced in court as common law. Never mind that there are contradictory proverbs: contradictory legal opinions clash in American courts every day.

My old man hadn't been using conventional debate and logic, perhaps, but he was exercising some skills that constitute a legitimate alternative for many peoples of the world. Okay, two can play that game. Armed with two degrees, two published books, and a few more years of experience, I returned home, ready to deal with Dad.

"I wonder if you'd loan me enough to buy a new car, Dad. After all, 'As the twig is bent, so grows the tree.' "

"Champagne thirst, beer budget," he responded.

"Well, maybe, but 'the Lord helps him who helps himself.' 'Nothing ventured, nothing gained,' " I said, firing both barrels at once.

"Wer nicht hoert, muss fuehl."

"Well, I'm ready to take my own lumps but, Pop, 'a burned child fears the fire.' "

"Eigenlob stinkt," he said over the top of his newspaper. "Vanity stinks." End of conversation. *Schluss*. I was left proverbless. Hmmm. Apparently I hadn't learned enough proverbs. Education or not, I was still outclassed when it came to dueling proverbs.

On one particularly memorable occasion, I thought I had him cornered. We were arguing about what keeps airplanes up. He said no one really understands. I talked aerodynamics and noted that I learned all this stuff in Air ROTC when I was in school. I explained that air passing at high speed over the airfoil generates low pressure on the top. I did end runs around his "The proof of the pudding is in the eating" and "A man convinced against his will is of the same opinion still." I dismissed "For every pot there's a lid" as irrelevant and countered "Look before you leap" with "He who hesitates is lost."

Thrust and parry, lunge and retreat, slash and burn. Then I abandoned his game and tried to get the momentum going my way. I turned to science. I explained venturi tubes, drag, speed, lift, all those things. Finally I turned to the television set where Bobby Rahal was explaining the ground-effects race car. He talked about venturi tubes, airfoils, drag, speed, lift, all those things. Rahal, a brainy guy as well as a top-notch car driver, used a diagram board and drew precisely the same ideas I had been trying to explain to Dad. For me, it was like a gift from heaven. I had independent, expert verification for my position, right there in front of us, with no possibility of Dad blowing it all away with some proverb.

In triumph I crowed and pointed to the television set. "There you have it, Dad. Irrefutable evidence that I am right."

"The exception proves the rule," he smiled.

I'm now fifty-five years old and he's seventy-eight and I don't even try anymore. "There's more than one way to skin a cat."

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

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AT THE AMERICAN MUSEUM

AT THE PLANETARIUM

A progress report on the newest discoveries of the Hubble Space Telescope is the subject of an illustrated talk by Eric Chaisson, director of educational programs and senior scientist at the Space Telescope Science Institute of Johns Hopkins University.

The lecture—on Wednesday, April 29, at 7:30 P.M. in the Planetarium's Sky Theater—is part of the "Frontiers in Astronomy and Astrophysics" series. Tickets are $6 ($5 for members).

For additional information about specific Planetarium happenings, call (212) 769-5900.

CHINA MONTH

The American Museum celebrates China Month throughout April with presentations of Chinese music, dance, art, theater, and literature. Events include performances by the Galápagos Puppet Theater and the Nai-Ni Chen Dance Company and talks on such subjects as the Silk Road, the aesthetics of Peking Opera, Taiwanese theater, and art trends. Except for April 18 and 19, the events take place each Saturday and Sunday between 1:00 and 4:30 P.M. in the Leonhardt People Center and the Kaufmann Theater. There is an admission charge to enter the Museum, but no additional charge for these programs. Seating is on a first-come, first-served basis. No tickets are necessary. These programs, presented by the Museum's Department of Education, are made possible in part by the generosity of the Vidda Foundation. For a full schedule of events, call (212) 769-5315.

"PEOPLE OF THE FOREST"

Orangutans, the now endangered, elusive, tree-dwelling great apes, are the sub-

"Ribbon Dance," by the Nai-Ni Chen Dance Company
Martha Swope Associates/Carol Rosegg

ject of a talk by Biruté Galdikas, who has set up an orangutan research center in Tanjung Puting National Park in Indonesia. Speaking in the Main Auditorium at 7:00 P.M. on Thursday, April 9, Galdikas will discuss her conservation efforts, as well as her many discoveries about the ecology of these shy red apes. Tickets are $25 ($15 for members).

The Casbah Dance Experience

The Casbah Dance Experience, directed by Carolina Varga Dinicu (also known as Morocco), performs ethnic dances from the Middle East and North Africa on Sunday, April 5, at 2:00 P.M. On the program are a mystical dance of benediction and thanksgiving, an Egyptian cane dance, and several romantic and humorous dances to traditional Middle Eastern and North African music. The program will be held in the Kaufmann Theater, and tickets cost $10 ($6 for members).

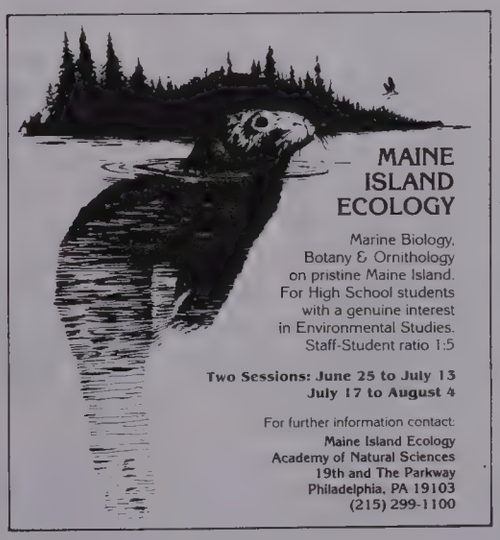
Evolution of Indian Clothing

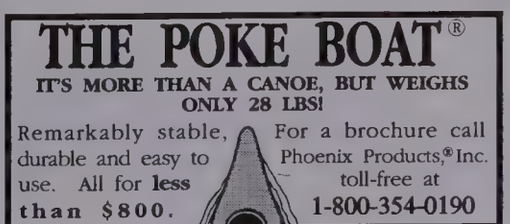
Anthropologist Chantal Boulanger lectures on the evolution of Indian clothing on Friday, April 10, at 7:00 P.M. in the Linder Theater. Boulanger will highlight fashion trends over the past two millennia, including the probable influence of the Greek and Roman toga and the effects of India's trade with Egypt. For more information, call (212) 769-5606.

Town Meeting

The Museum's Ecology Club, in collaboration with members of the Youth Sierra Club at the 92nd Street Y and the Junior Academy of the Academy of Sciences, is sponsoring a town meeting to address the solid waste crisis facing New York City. The Ecology Club is a junior and senior high school student organization dedicated to investigating environmental problems and actively pursuing their resolution. The meeting will be held in the Kaufmann Theater on Wednesday, April 8, at 6:30 P.M.

These events take place at the American Museum of Natural History, located on Central Park West at 79th Street in New York City. The Kaufmann and Linder theaters and the Leonhardt People Center are located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

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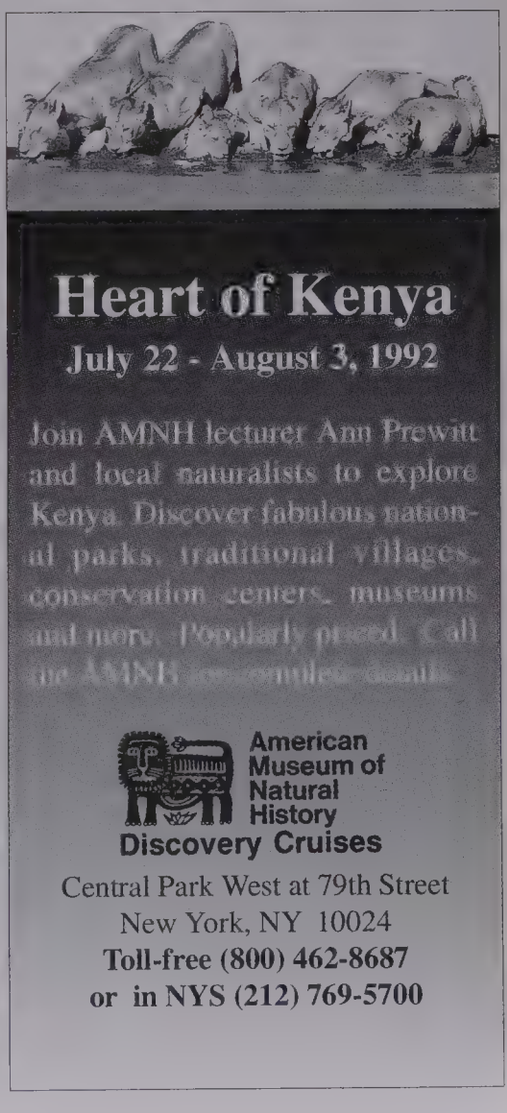
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Montserrat's Secret Gardens

Against all odds, some West Indian slaves managed to create their own economy and to invent a cuisine

by Raymond Sokolov

In this quincentenary year, much has already been said about the Columbian exchange of cultures and commodities after 1492, but the most eloquent statement is entirely lacking in words. I refer to the great corn portal that is serving as an entrance to the "Seeds of Change" exhibition at the National Museum of Natural History in Washington, D.C. Here, hundreds of ears of colorful Indian corn have been affixed to a columnar baroque arch.

Passing through this joint symbol of New World fecundity and Old World civilization, one continues on through a set of diverse galleries filled with every kind of relic and diorama, from Colombian emeralds to Amerindian horse regalia to a Mexican colonial *biombo,* or "screen," that combines Asian and European art to depict Cortés's conquest and its results. The organizing principle behind this polymorphous array was a somewhat arbitrary but provocative choice of five "seeds" to illustrate the impact of 1492: sugar, maize, disease, the horse, and the potato.

Well along in the exhibition, one emerges in a somber mood from the simulated interior of a slave ship into a reproduction of a village scene on the Caribbean island of Montserrat. There is a full-size planked hut on pilings; a one-room modern-day general store that visitors can enter; a sophisticated photodiorama that shifts dramatically between the pre-contact rain forest and a full-blown plantation with cane fields, a mill, slave shacks much like the "real" dwelling across the gallery, and the planter's house. In a display case are coins, potsherds, fragments of Staffordshire pearlware from 1825, and a slate pencil—relics of plantation life excavated from the ruins of Galways plantation on Montserrat.

This evocative section of "Seeds of Change" is the brainchild of Lydia Mihelič Pulsipher. She is a cultural geographer at the University of Tennessee at Knoxville and has spent years excavating at Galways plantation and looking into the history of Montserratian horticulture.

For someone who has not been following recent research in Caribbean archeology and social history, Pulsipher's work comes as a welcome surprise. She has been digging, literally and figuratively, into the physical evidence and documents that throw light on the life of African slaves on Montserrat. In particular, she has been able to show that slaves raised much of their own food in gardens they tended during precious spare time from plantation work. Some of these gardens were at a distance from the slave village, high in the mountains where growing conditions were better for certain crops, such as the tuberous rhizome called dasheen, one of the various starchy vegetables known in the English-speaking Caribbean as ground provisions.

In an imaginative reconstruction of a Sunday in slave days in the early nineteenth century, Pulsipher writes:

> In a moment Margaret will join Beneba, Lettice, Cumba, and Jenny Ebo for the hour's walk to market; but first she reminds Garrick to bring some dasheen down from her mountain ground at Gadinge and shallots and thyme from his garden at Hog Island.... The fertile dasheen plot was first worked by Judy Congo, an African woman who was grandmother to Margaret and Venus. The use of the steep plot at Hog Island comes to them through Garrick's family, having been passed from uncle to nephew for several generations. Lying in a steep ravine within ten minutes of the plantation, it is prized for its covert convenience. A third plot lies with many others on a strange tabletop land formation completely surrounded and shielded from view by deep forested ravines. This secret garden also can be quickly reached from the slave village but only via a steep treacherous track. The plantation manager knows of the existence of these gardens, but he has never taken the trouble to look for them since they cannot be easily reached on horseback. Almost daily his own kitchen is furnished with slave-grown produce, some of which is given to him and some of which he buys at reasonable rates.

In this way, in the middle of a brutally efficient and cruel slave system, slaves carved out their own quasi-legal, capitalist market-garden system and established de

West Indian marketwomen "heading-up" their wares
National Library of Jamaica, Kingston

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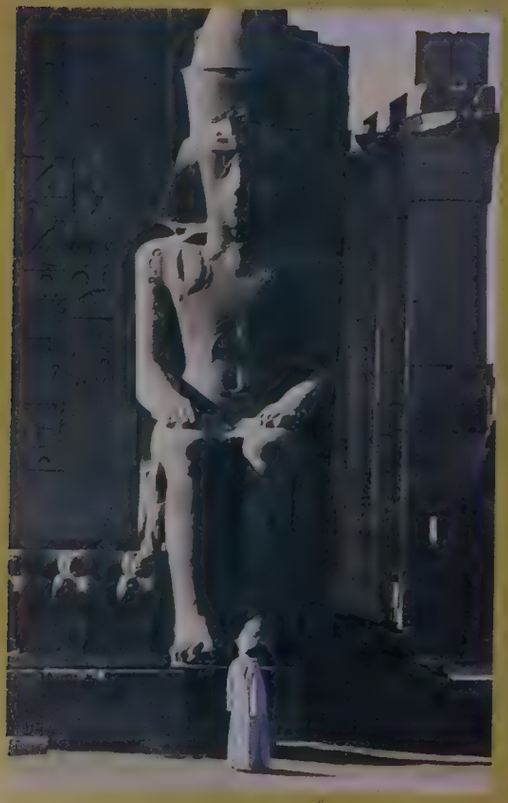

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facto rights to land and to control over their own leisure time.

This "life-affirming saga of resilience, resistance and creative adaptation" is not an isolated phenomenon. In a pioneering paper published in 1960, Sidney M. Mintz and Douglas Hall presented similar evidence of an internal market-garden system in Jamaica. In "Seeds of Change," David Barry Gaspar paints a parallel picture of Antiguan slaves fighting to assert themselves against the "worst tendencies within slavery" by finding ways to take a greater part in the economic life of the island, in particular through gardening.

Cooking was another area in which slaves mastered their new and restricting environment. Pulsipher reminds us that slaves adapted African plants to plantation life and that they learned about local plants from the indigenous Indians. Native cassava became a slave staple, and evidence from the dig at Galways slave village shows that slaves may have improvised the mass production of cassava "as an entrepreneurial activity. They used metal griddles, rather than the stone-shard board graters, basket presses and sieves, and clay griddles of the native tool complex."

In their kitchens, slaves mixed New and Old World foods to invent a post-Columbian cuisine. The ceremonial stew of Montserrat called goatwater combines West African (Yoruba) sacrificial ritual elements with New World ingredients. Duchno, a dish with a name probably derived from an African word for millet, is a mix of native (sweet potatoes, peppers), Asian (sugar, coconut), and Near Eastern (wheat flour) ingredients, wrapped in a banana leaf and then boiled.

Perhaps the most interesting of these post-African garden-kitchen adaptations arose when slaves applied themselves to the production and consumption of the taro in the West Indies. I use the term *taro* loosely for a very large and various group of related plants, because it has the widest currency in English as a name for edible members of the arum, or Araceae, family (aroids include 2,000 species and 115 genera, including decorative philodendrons, dieffenbachia, and calla lilies). The best-known taro dish is poi, the mucous Polynesian mush made from the plant's tuberous rhizome and universally detested by tourists at staged luaus.

The taro behind this gastronomic nightmare is known, in myriad species and cultivars, throughout warm parts of the Old World, from Pacific Asia to Africa. The genus is *Colocasia.* Its leaves are similar to spinach and are most frequently encountered in the Caribbean soup called calalu. The tuberous rhizome (hereinafter to be referred to as root) is a starchy food source that, like all aroids, contains calcium oxalate crystals in its sap. These cause severe, long-lasting pain if ingested when the root is raw. Cooking removes the danger.

Colocasia had reached West Africa and established itself in local diets long before 1492. As a result of the slave trade, *Colocasia* was naturalized in the islands, where it goes by a confusing multiplicity of names descended from words in various

Multicultural Shepherd's Pie

This recipe combines the culinary traditions of Montserrat's two imported forced-labor forces—indentured Irish workers and African slaves. Traditional shepherd's pie tops ground lamb with a layer of mashed potatoes. Here two typical island ingredients—dasheen and goat—are substituted. Actually, both the traditional and this shepherd's pie are multicultural, since neither lamb nor potato were indigenous to the British Isles, while goat and dasheen were both imported to the Caribbean. Goat came first with the Spanish.

1¼ pound dasheen (also sold as malanga) or potatoes, peeled and cut in large chunks
Salt
Milk
1 pound (4 cups) cooked goat meat (or leftover lamb or beef)
2 cloves garlic, finely chopped
1 tablespoon chopped cilantro (or rosemary)
5 tablespoons lard (or butter or oil)
2½ tablespoons flour
1¼ cup meat stock
Pepper

1. Boil dasheen in lightly salted water to cover until just tender, 20 to 25 minutes. Press through the medium disk of a food mill. Smooth out with milk.
2. Combine goat meat, garlic, and cilantro. Chop fine in food processor.
3. Preheat oven to 375 degrees.
4. Heat lard, add flour, and cook over low heat until the flour browns. Stir in goat mixture, add meat stock, and cover.
5. Transfer meat mixture to 2-quart casserole. Spread dasheen purée over the meat mixture.
6. Bake for 35 to 40 minutes or until dasheen is browned.

Yield: 8 servings

African languages: dasheen, tania, eddo, malanga, coco.

To complicate matters further, there already was another edible aroid under cultivation in the Caribbean before 1492. Some forty species of *Xanthosoma* go by the vernacular names of tania, tannier, malanga amarilla, yautia, and cocoyam. The nomenclatural overlap with vernacular names for *Colocasia* makes identification especially difficult for the neophyte. Fortunately, most North American retail sources, which are usually Hispanic, deal in two fairly distinguishable varieties. The *Colocasia* is most often a smoothly cylindrical, lightly hairy root whose brown rind shows pink underneath when peeled. The white flesh shows patterns of dark lines, which Elizabeth Schneider, in *Uncommon Fruits and Vegetables* (Harper and Row, 1986), says remind her of grated chocolate. The Manhattan supermarket I use sells *Colocasia* as malanga and merchandises *Xanthosoma* as yautia.

The yautia I see at the market are gnarled and hairier than the malangas. The flesh, visible through the rind, has a yellow cast to it. When sliced, it is a pure white. Forced through a food mill, the flesh emerges dry and crumbly, but when mixed with a small amount of milk it turns into a smooth paste somewhat like mashed potatoes. The taste is strong, earthy, and vaguely metallic. If cooked long enough, yautia breaks down into a smooth, creamy substance that blends easily with and thickens stews or mixes well with other root vegetables, as in the plantain dough for Puerto Rican *alcapurria* fritters.

The taste of malanga is similar to yautia's but more assertive. After cooking, the flesh turns purple. Malanga should probably not be eaten by itself as a purée, but in combination with other foods or fried as chips.

This discussion only scratches the surface of an extremely intricate subject. But its complexity was an open book to slave gardeners and cooks. Island recipes call for one variety of aroid or another with great specificity. And slave gardeners also treated *Colocasia* and *Xanthosoma* knowingly, according to their special cultural requirements. Pulsipher's research shows that the moist conditions of the high, "secret" gardens of Montserrat (and elsewhere in the region) favored the cultivation of Old World *Colocasia*. So in those bravely nurtured aeries, slaves stole time and land from their masters to keep alive the edible heritage of Africa.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

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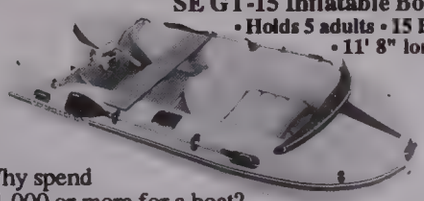

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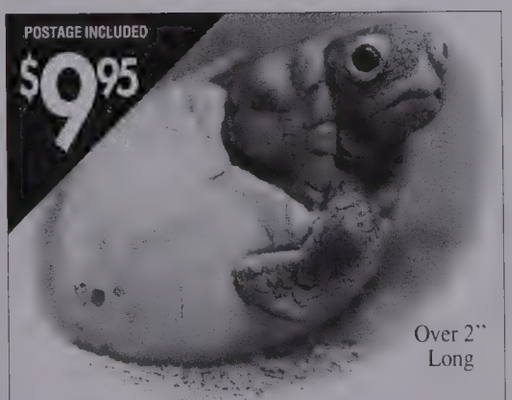

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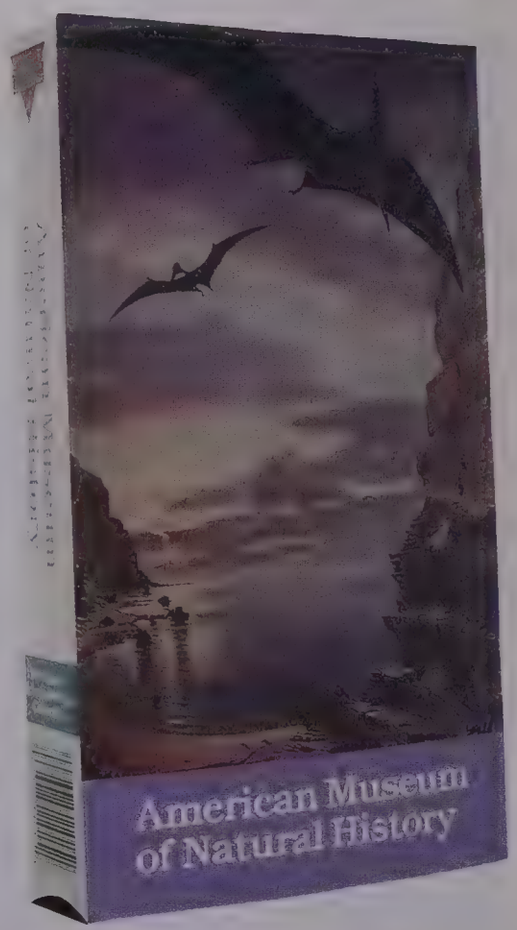

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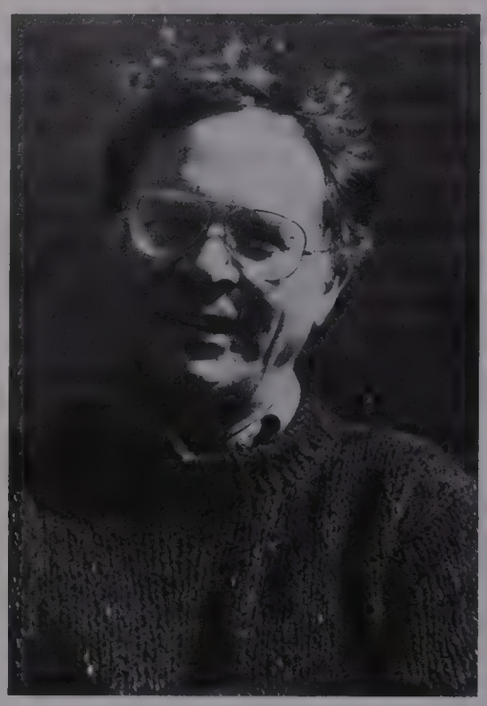
Road Show

Some lions are less inhibited than others. Often an amorous pair will discreetly leave the pride for a secluded spot. Others exchange intimacies while relatives, rejected suitors, and curious cubs look on. But one indication of the degree to which tourist vehicles have been accepted by wildlife in African preserves is this scene in South Africa's Kalahari Gemsbok National Park. The photographer watched this preoccupied pair for about half an hour as traffic jammed and cameras whirred.

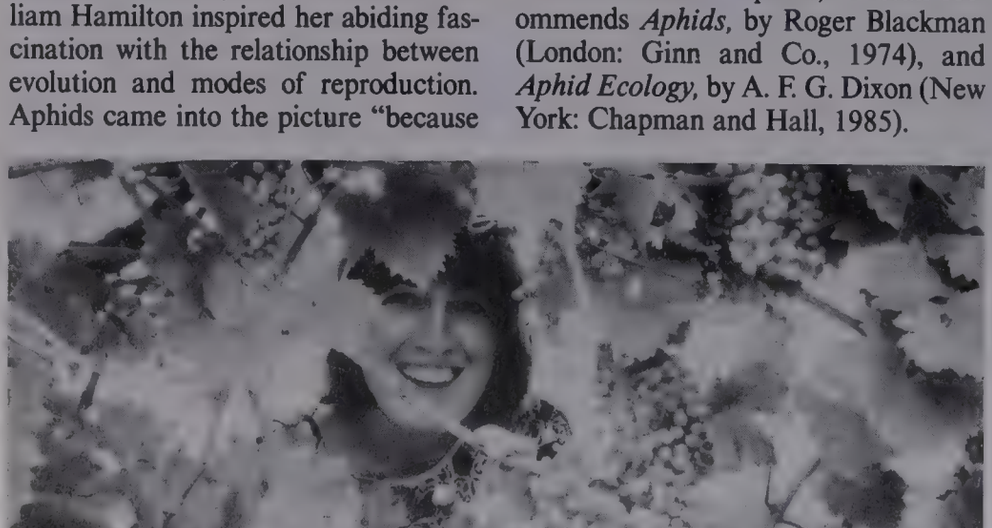
A female lion's receptive period, known as estrus, lasts about a week. A male is quick to perceive the signs. When the lioness accepts his advances, the two pair off and are not out of each other's eyeshot all week. They tend not to roam or even eat. Because lionesses do not ovulate until after they have been stimulated repeatedly, the week is devoted to copulation. While mating, the male often grasps his consort's neck in his jaws; his teeth rest on but do not pierce her skin. Occasional toothy snarls may remind both parties of the powerful potential of each, but constancy and a gruff fondness are sometimes evident, and reproductively effective. The vanned voyeurs were most likely treated to an encore; during estrus, lions mate about 100 times a day.—*J. R.*

Photograph by
Thomas Dressler



Long before global warming became a hot topic, **Wallace S. Broecker** (page 6) was investigating how the climate has changed over geological time. He has been particularly interested in how shifts in large ocean currents can amplify small changes in the climate, bringing about rapid warming or cooling of the earth. Broecker completed his undergraduate and graduate studies at Columbia University and is now a professor of geology at the university's Lamont-Doherty Geological Observatory. He served as one of the scientific advisors for the American Museum's upcoming special exhibition "Global Warming—Understanding the Forecast." For further reading on climate change within the recent past, Broecker recommends Jean Grove's *The Little Ice Age* (London: Routledge, 1990).

"I liked bugs as a kid, but I wasn't a science nerd early on," says **Nancy A. Moran** (page 34), now an associate professor of ecology and evolutionary biology at the University of Arizona at Tucson. It wasn't until a junior-year course in biology at the University of Texas turned her on to the ideas of evolution and natural selection that she was transformed from an art major into a biologist. Later, graduate courses at the University of Michigan with evolutionary theorists John Maynard Smith and William Hamilton inspired her abiding fascination with the relationship between evolution and modes of reproduction. Aphids came into the picture "because they can be sexual or not," she explains, and thus are ideal organisms to work with "in testing ideas about the evolutionary costs and benefits of sex." Moran's current research interests include the evolution of multiple phenotypes within species and associations between insects and their intracellular bacterial symbionts. Although she loves "hiking and botanizing," her all-absorbing recent "hobby" has been her baby girl, born this past September. For "lots of information on aphids," Moran recommends *Aphids,* by Roger Blackman (London: Ginn and Co., 1974), and *Aphid Ecology,* by A. F. G. Dixon (New York: Chapman and Hall, 1985).



Measuring the paws of a tranquilized young puma was all in a day's work fo **Warren E. Johnson** (page 26) during hi four-year field study of predators i Patagonia's Torres del Paine Nationa Park. One result of his stay was the arti cle on foxes in this issue. Another wa that he met his wife, Mariane, who was Chilean tourist visiting the park. (The now live in Ames, Iowa, with their year

old son, Daniel.) Born in Bangkok, Thailand, Johnson acquired his taste for natural history while growing up in the Philippines and later in Peru, where his peripatetic father would take the family camping in remote wilderness areas. After completing undergraduate work at Oberlin College and gaining a master's degree in wildlife ecology from Utah State University, Johnson is now working on his doctorate at Iowa State University. William Franklin, his zoological mentor and an expert on vicuñas and guanacos, steered Johnson's interests to the animals and ecosystems of Patagonia. For further reading on the region's wildlife, Johnson recommends *Attending Marvels: A Patagonian Journal,* by George Gaylord Simpson (Chicago: University of Chicago Press, 1982), and *In Patagonia,* by Bruce Chatwin (New York: Viking Penguin, 1988).

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In 1989, when 100,000 banded stilts where discovered nesting in South Australia, **Keith Bellchambers** and **Graham Carpenter** (page 42) were ready on short notice to investigate life in the huge colony. Although common along parts of the coast, the birds had never been studied in depth during their breeding cycle. Bellchambers and Carpenter flew to the colony by helicopter and were dropped off with a full month's supplies. They recorded, for the first time, the details of banded stilt nesting from courtship to the fledging of chicks. A technical officer for the Arid Zone Research Institute in Alice Springs, Northern Territory, Bellchambers, above, has assisted researchers in Papua New Guinea in studies of birds of paradise and bower birds. His main project, however, involves the reintroduction to the wild of an endangered Australian mammal, the bilby. Carpenter, below, a scientific officer with the South Australian Department of Environment and Planning in Adelaide, has long been interested in the ecology of wading birds. In addition to ornithology, he studies botany and is "a jaffle [a cross between a pie and a waffle] maker of some repute." He enjoys any opportunity to get out into the bush and combine the three interests. More information on banded stilts is available in *The Atlas of Australian Birds,* by M. Blakers, S. J. J. F. Davies, and P. N. Reilly (Melbourne: Melbourne University Press, 1984), and John Douglas Pringle's *The Shorebirds of Australia* (London: Angus and Robertson Publishers, 1987), with photographs provided by the National Photographic Index of Australian Wildlife.

Daphne Gail Fautin (page 50) has spent many hours underwater on coral reefs studying clownfish, which live under a sea anemone's protective umbrella. But the subject of her article, deep-sea hermit crabs and their anemones, which spin golden shells, arrived at her office in jars. Nevertheless, as an anemone taxonomist, she welcomed the chance to inspect this unusual symbiotic pair. Fautin, who received her Ph.D. from the University of California at Berkeley, recently moved from her job as director of research and associate curator of invertebrates at the California Academy of Sciences to the Snow Museum of the University of Kansas, where she is an adjunct professor. Although she lives far from the sea, Fautin travels frequently, pursuing her interest in marine life. She plans to extend her research to include the molecular evolution of sea anemones and corals. A licensed pilot, Fautin enjoys flying as well as gourmet cooking. For additional reading on hermit crabs and anemones, she recommends "The Hermit Crab's Special Forces," an article by Randy Brooks in *Sea Frontiers,* July–August 1990.

The two accommodating lions in this month's "Unnatural Moment" (page 76) rewarded tourists hoping for a close-up encounter with wildlife in South Africa's Kalahari Gemsbok National Park. The catch for the tourists was sharing the intimate look with vanloads of their fellows. Photographer **Thomas Dressler** captured the irony of the primal scene played out in traffic last June. A native of Germany, Dressler has lived in Spain for ten years and resides near Malaga on the southern coast. Before becoming a professional photographer five years ago, he led tours in Spain and North Africa. Dressler plans to travel to Australia next year and is currently working on a book of photographs of Africa.

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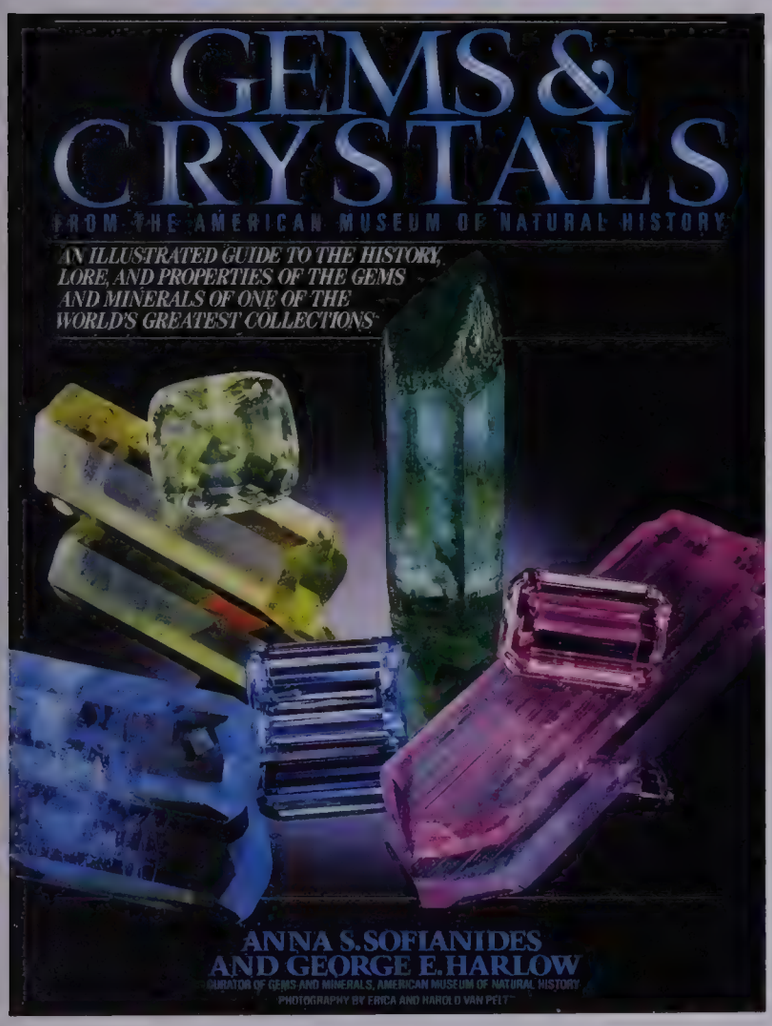
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MAY 1992

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NATURAL HISTORY (ISSN 0028-0712) is published monthly by the American Museum of Natural History, Central Park West at 79th Street, New York, N.Y. 10024. Subscriptions: $25.00 a year. In Canada and all other countries: $34.00 a year. Second-class postage paid at New York, N.Y., and at additional mailing offices. Copyright © 1992 by American Museum of Natural History. All rights reserved. No part of this periodical may be reproduced without written consent of *Natural History*. Send subscription orders and undeliverable copies to the address below. Membership and subscription information: Write to address below or call (800) 234-5252 if urgent. POSTMASTER: Send address changes to Natural History, Post Office Box 5000, Harlan, IA 51537-5000.

The Most Unkindest Cut of All

"What can be more insane than madness that constructs its own byzantine taxonomy?"

by Stephen Jay Gould

Consider this unremarkable description of a perennially pleasant pastime: unwinding after a hard day's work—a smoke and a drink around the fire:

I remember that at the end of this ——— conference, ——— and I sat very cozily near the stove and then I saw ——— smoke for the first time, and I thought to myself, "——— smoking today"; I'd never seen him do that. "He is drinking brandy": I hadn't seen him do that for years.... We all sat together like comrades. Not to talk shop, but to rest after long hours of effort.

Now let's play "fill in the blanks." The man who made such an exception to his usual abstemiousness in order to celebrate his pleasure at such a successful outcome? Reinhard Heydrich, head of the Nazi security police and chief deputy to SS director Heinrich Himmler. The location of the cozy stove? The Wannsee Conference of January 20, 1942, held to prepare a plan for the *Endlösung der Judenfrage*— the "final solution to the Jewish question," the systematic murder of 11 million human beings (by Heydrich's own reckoning) and the genocide of a people. The man who remembered the closing scene quoted above? Adolf Eichmann, another participant and author of the Wannsee Protocol, the infamous document that summarized the hard day's work.

The maximally chilling content of the Wannsee Protocol is enhanced by its euphemistic and circumlocutory language. Killing and murder are never mentioned directly, and genocide sounds even more evil (if anything can make the ultimately hateful still worse) in its obtuse, but unmistakable, description as a "final solution." But Eichmann, at his trial, recalled that the verbal discussions could not have been more direct:

What I know is that the gentlemen convened their session, and then in very plain terms—not in the language that I had to use in the minutes, but in absolutely blunt terms—they addressed the issue, with no mincing of words.... The discussion covered killing, elimination, and annihilation.

In its evasive first half, the Wannsee Protocol enumerates the Jewish population of Europe at some 11 million and then reviews the first two stages of former action, now deemed unsuccessful and insufficient. At first, Hitler and company attempted "the expulsion of the Jews from every particular sphere of life of the German people"—read *Kristallnacht*, confiscation, and terrorism. The second strategy stressed physical removal: "the expulsion of Jews from the living space [*Lebensraum*] of the German people." But, Eichmann writes in the Wannsee Protocol, emigration spawned too many obstacles and had not worked fast enough:

Financial difficulties, such as the demand for increasing sums of money to be presented at the time of the landing on the part of various foreign governments, lack of shipping space, increasing restriction of entry permits, or cancelling of such, extraordinarily increased the difficulties of emigration.

On, then, to a third (and truly ultimate) "solution"—kill them all. (In some sense, as so many others have noted, the most chilling aspect of the Wannsee Conference and Protocol, held to initiate and implement this third strategy, lies neither in Heydrich's ability to conceptualize evil at such grand scale nor in Eichmann's

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propensities for composing plans in euphemistic bureaucratese, but in the painstaking and deliberate construction of detailed logistics for such an extensive undertaking—the careful calculation of railroad cars and their volumes, the siting of death camps at the hubs of transportation lines, complex efforts to mask the true intent by depicting genocide as relocation and forced labor.) Eichmann then introduces the new plan: "Another possible solution of the problem has now taken the place of emigration, *i.e.*, the evacuation of the Jews to the East, provided the Fuehrer agrees to the plan" (Hitler had, in fact, already ordered such a strategy). Eichmann continues with his masked description of forced transportation to death as emigration for labor:

> Under proper guidance the Jews are now to be allocated for labor to the East in the course of the final solution. Able-bodied Jews will be taken in large labor columns to these districts for work on roads, separated according to sexes, in the course of which action a great part will undoubtedly be eliminated by natural causes.... In the course of the practical execution of this final settlement of the problem, Europe will be cleaned up from West to East.... The evacuated Jews will first be sent, group by group, into so-called transit ghettos from which they will be taken to the East.... It is intended not to evacuate Jews of more than 65 years of age but to send them to an old-age ghetto.

Some camps—most notably Auschwitz–Birkenau—served both as killing places and prisons for forced labor (only a slower form of death). But others were gassing sites pure and simple—Treblinka, Chelmno, Sobibor, Belzec. Architects of the final solution never intended to implement their "cover story" of transportation for labor. We sometimes get a false impression of immediate death versus starvation and forced labor at the camps—although little preference can be specified in such a grisly "Sophie's choice." Several thousand survived Auschwitz–Birkenau, and many have told their stories. But the pure death camps are less well known because virtually no one survived: only two people at Belzec; three at Chelmno (*see* M. Gilbert, *The Holocaust*). The final solution was always and only about murder—total and unvarnished.

Clearly, I have nothing to add to this ultimate story of human atrocity. I am neither a poet nor historian, and I was not there. Why take up such a subject in a series of columns on natural history and evolutionary theory? The answer lies in the second half of the Wannsee Protocol (and in a crucial first-half paragraph that shall serve as the crux of this essay)—the section that is rarely discussed and almost never quoted. The rationale also rests with Hitler's misuse of genetics and evolutionary biology as a centerpiece of plans explicitly stated right from the beginning, at the publication of *Mein Kampf* in 1925.

Insofar as Hitler's evil schemes should be dignified by the term "theory" at all, he sunk his argument squarely in paranoia about racial purity and its biological necessity for triumphant peoples in a world of natural selection. The Aryan nation had been great, but its strength had been sapped by racial mixing, encouraged by the insidious and liberal propaganda of parasitic Jews, out to rule the world or at least to feed off the higher morality of Aryan virtue. Hitler wrote in *Mein Kampf:*

> The Aryan gave up the purity of his blood and therefore he also lost his place in the Paradise which he had created for himself. He became submerged in the race-mixture, he gradually lost his cultural ability till ... he began to resemble more the subjected and aborigines than his ancestors. ... Blood-mixing, with the lowering of the racial level caused by it, is the sole cause of the dying-off of old cultures; for the people do not perish by lost wars [a comment on Germany's defeat in World War I], but by the loss of that force of resistance which is contained only in the pure blood. All that is not race in this world is trash.

(I am quoting from the first complete English translation of *Mein Kampf,* published in America by John Chamberlain and others in 1939 as a warning about the enemy we would soon need to confront. My parents bought this book before my father left to join the battle. Throughout my youth, I stared at this volume on my parents' shelves, taking it down now and again—more to experience the *frisson* of touching evil than from any desire to read. When my father died a few years ago, and my mother offered me his collection of books, I included this familiar volume with its blood red jacket among the few items that I wanted for my own. To hold it now, and to quote from it for the first time, gives me an eerie feeling of connectivity with my past and rekindles my dimmest three-year-old impression that World War II was a fight between my daddy and a bad man named Hitler.)

If the first (and oft-quoted) half of the Wannsee Protocol is a cursory and euphemistic account of genocide at work sites and death camps, the highly specific (and usually neglected) second half is a detailed and specific disquisition on genetics and race mixing—and for an obvious reason, given Hitler's eugenic ideas. From the Fuehrer's standpoint, killing 11 mil-

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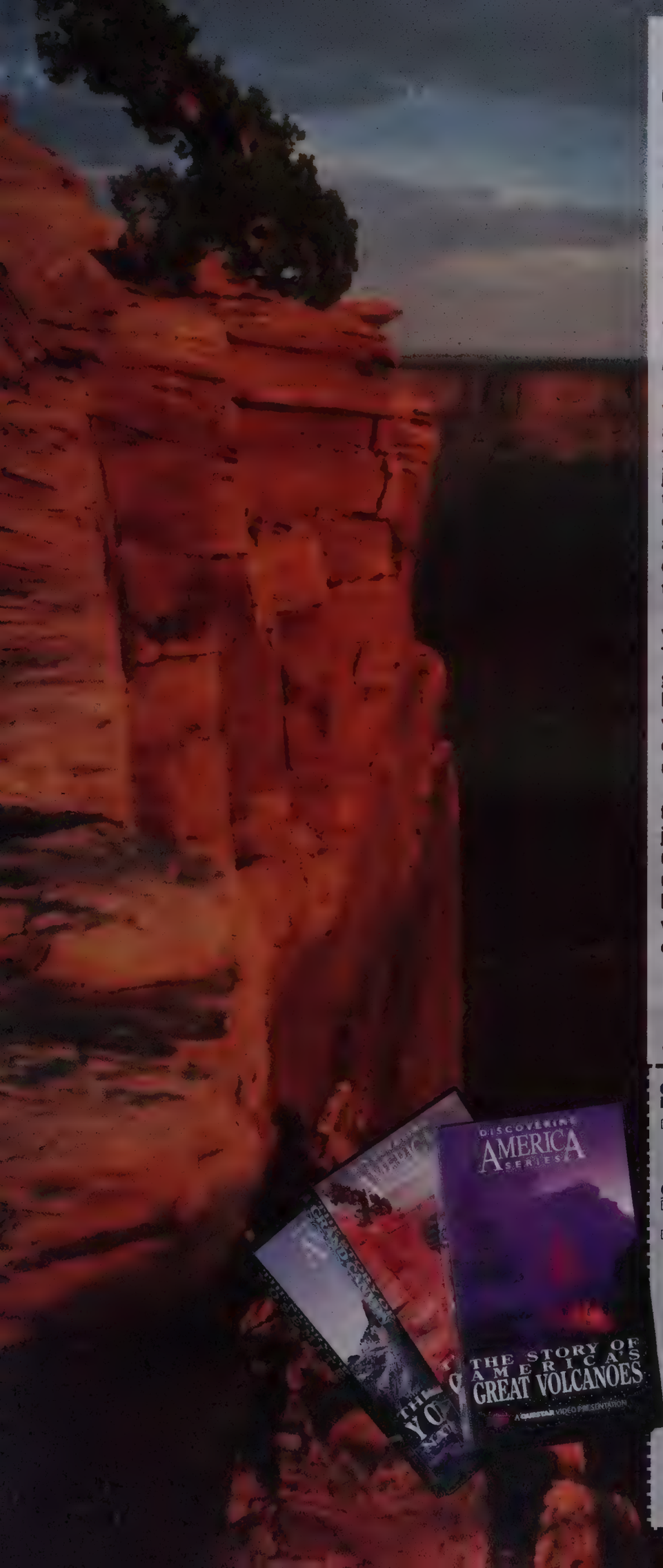

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lion people will not solve the Jewish problem if many German citizens still carry tainted blood as a result of partial Jewish ancestry through mixed marriages. A truly final solution demands a set of rules and policies for these *Mischlinge* (literally, mixtures). Kill the others and purify yourselves. The two halves of the protocol could not be more intimately connected through the sick logic of Hitler's racial doctrines. Eichmann's transition sentence, written in optimally opaque bureaucratese, states:

> The implementation of the final solution problem is supposed to a certain extent to be based on the Nuremberg Laws [Nazi legislation on eugenic marriage and sterilization], in which connection also the solution of the problems presented by the mixed-marriages and the persons of mixed blood is seen to be conditional to an absolutely final clarification of the question.

These pages on racial mixing reveal a form of madness different from Eichmann's first half on genocide in the east. If the first part of the protocol wallows in the ultimate evil of euphemized mass murder, this second half follows the steely logic of total craziness reasoned right through, with full coverage of all details. Only once before have I experienced such a feeling while reading an official state document: when I studied the annual proceedings of the South African racial classification board as they tortured the logic of continuity to find a discrete pigeonhole for each individual under strict apartheid.

Needless to say, any such effort faces an intractable dilemma at the start: people are complexly interbred at all degrees of mixture, and neither pure solution will work. Is everyone with even the slightest trace of Jewish ancestry a Jew (which would condemn most of the nation) or does salvation arise with any Aryan infusion (which would be far too lenient for zealous madmen)? Heydrich, Eichmann, and company therefore invoke the usual trick of argument for breaking a true continuum that lacks a compelling point for separation: choose an arbitrary dividing line and then treat it as a self-evident law of nature.

The protocol basically proclaims: half-breeds are Jews (offspring of one pure Jewish and one pure Aryan parent); quarter-breeds are German (offspring of a half-breed and an Aryan). But this tidy little rule required some nuancing at the borders. At one end, half-breeds could avoid their death warrant if they had children by marriage to a person of German blood (but not if such a union had no offspring) or "if exemption licenses have been issued by the highest Party or State authorities."

Even this hope for mitigation carried two provisos: first, each exemption must be granted on a case-by-case basis and only for "personal essential merit of the person of mixed blood." Second, anyone so spared must make a little gesture in return: "Any person of mixed blood of the first degree to whom exemption from the evacuation is granted will be sterilized—in order to eliminate the possibility of offspring and to secure a final solution of the problem presented by the persons of mixed blood." But wait, fear not: "The sterilization will take place on a voluntary basis." Consider the alternative, however: "But it will be conditional to a permission to stay in the Reich." One participant at the conference made an astute observation on this score:

> SS-Gruppenfuehrer Hofmann advocates the opinion that sterilization must be applied on a large scale; in particular as the person of mixed blood placed before the alternative as whether to be evacuated or to be sterilized would rather submit to sterilization.

At the other end, the supposedly acceptable quarter-breeds could be "demoted" to genocide for any of three reasons, all designed to ferret out an unacceptable degree of racial taint: (1) "The person of mixed blood of the second degree is the result of a marriage where both parents are persons of mixed blood" (apparently, a child needs at least one purely Aryan parent to enter the realm of the blessed); (2) "The general appearance of the person of mixed blood of the second degree is racially particularly objectionable so that he already outwardly must be included among the Jews"; (3) "The person of mixed blood of the second degree has a particularly bad police and political record sufficient to reveal that he feels and behaves like a Jew."

In the gray area between, marriages of two people with mixed blood sealed everyone's doom, parents and children alike. Even a normally exempt quarter-breed must die (with all children) if such a person marries a half-breed:

> Marriage between persons of mixed blood of the first degree and persons of mixed blood of the second degree: Both partners will be evacuated, regardless of whether or not they have children . . . since as a rule these children will racially reveal the admixture of Jewish blood more strongly than persons of mixed blood of the second degree.

What can be more insane than madness that constructs its own byzantine taxonomy? Or are we just witnessing the orderly mind of the petty bureaucrat applied to human lives rather than office files?

The protocol's most stunning misuse of evolutionary biology, however, appears

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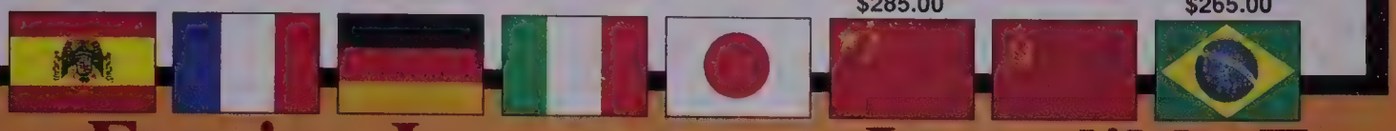

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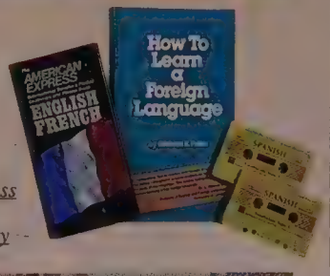

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not in this tedious taxonomy of genetic nonsense but right in the heart of the document's chief operational paragraph. I quoted the words previously, but left an ellipsis to signify an omission that I now restore. Eichmann speaks of deportation to the east, and of hard labor on the roads, leading to the death of most. He then continues (to flesh out my previous dots): "The possible final remnant will, as it must undoubtedly consist of the toughest, have to be treated accordingly. . . . " Let me now switch to the original German: "da dieser, eine natürliche Auslese darstellend, bei Freilassung als Keimselle eines neuen jüdischen Aufbaues anzusprechen ist." Or: "as it is the *product of natural selection* [italics mine], and would, if liberated, act as a bud cell of a Jewish reconstruction."

Perhaps you do not see the special horror of that line (embedded, as it is, in such maximal evil). But what can be more wrenching than the violation of one's own child, or the perversion for vicious purpose of the most noble item in a person's world? I am an evolutionary biologist by original training and a quarter century of practice. Charles Darwin is the resident hero in my realm—and few professions can name a man so brilliant, so admirable, and so genial as both founder and continuing inspiration. Darwin, of course, gave a distinctive name to his theory of evolutionary change—natural selection. The theory has a history of misuse almost as long as its proper pedigree. Claptrap and bogus Darwinian formulations have been used to justify every form of social exploitation—rich over poor, technologically complex over traditional, imperialist over aborigine, conqueror over defeated in war. Every evolutionist knows this history only too well, and we bear some measure of collective responsibility for the uncritical fascination that many of us have shown for such unjustified extensions. But most false expropriations of our chief phrase have been without our knowledge and against our will.

I have known this story all my professional life. I can rattle off lists of such misuses, collectively called social Darwinism (see my book *The Mismeasure of Man*). But until the fiftieth anniversary of the Wannsee Conference piqued my curiosity and led me to read Eichmann's protocol for the first time, I had not known about the absolute ultimate in all conceivable misappropriation—and the discovery hit me as a sudden, visceral haymaker, especially since I had steeled myself to supposed unshockability before reading the document. *Natürliche Auslese* is the standard German translation of Darwin's "natural selection." To think that the key phrase of my professional world lies so perversely violated in the very heart of the chief operative paragraph in the most evil document ever written! What symbol of misuse could possibly be more powerful? Surely this is the literary equivalent of imagining one's daughter shackled in a dungeon operated by sadistic rapists.

It scarcely matters that the phrase is so ludicrously inverted in its misapplication—for we dare hardly dignify Eichmann's argument with space for refutation. Natural selection is nature's process of differential reproductive success, however that advantage be attained (sometimes by dominating one's fellows to be sure, but also by cooperation for mutual benefit). What could be more unnatural, more irrelevant to Darwin's process, than the intricately planned murder and starvation of several million people?

I could simply end this essay here, washing my profession's hands of all conceivable responsibility. After all, the Wannsee Protocol would have proclaimed and implemented its horrors even if Eichmann had not employed Darwin's phrase to justify and embellish his major recommendation. And Eichmann's use, in any case, is a perverse misinterpretation of Darwin on both key grounds—the false application of a natural principle to human moral conduct and the distortion of a statement about differential reproductive success into a bogus validation of mass murder as natural. Of the latter mistake Darwin wrote in a key passage in the *Origin of Species:*

> I should presume that I use the term Struggle for Existence in a large and metaphorical sense, including dependence of one being on another, and including (which is more important) not only the life of the individual, but success in leaving progeny. Two canine animals in a time of dearth may be truly said to struggle with each other which shall get food and live. But a plant on the edge of a desert is said to struggle for life against the drought.

But resolutions are never so clean or simple. Science, as a profession, does have a little something to answer for, or at least something to think about. Darwin may have been explicit in labeling the struggle for existence as metaphorical, but most nineteenth-century versions (including Darwin's own illustrations, most of the

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time) stressed overt competition and victory by death—surely a more congenial image than peaceful cooperation for an age of aggressive expansion and conquest, both ethnographic and industrial.

Hitler didn't invent the mistaken translation to human affairs. Claptrap Darwinism had served as an official rationale for German military conquest in World War I (while our side often used the same argument, although less zealously and systematically). In fact, William Jennings Bryan first decided to oppose evolution when he mistook Darwin's actual formulation for the egregious German misuse that so deeply disturbed him (see my essay of November 1987).

Many scientists consistently opposed this misapplication, but others, probably the majority, remained silent (many enjoying the prestige, even if falsely won), while a few actively abetted the co-optation of their field for a variety of motives, including misplaced patriotism and immediate personal reward. Several English and American eugenicists offered initial praise for Hitler's laws on restriction of marriage and enforced sterilization—before they realized what he was really up to. And the text of this legislation borrowed heavily from eugenical sterilization statutes then on the books of several American states and upheld by the Supreme Court in 1927. German evolutionists did not raise a chorus of protest against Hitler's misuse of natural selection, dating to *Mein Kampf* in 1925. Wannsee is the logical extension of the following fulmination in *Mein Kampf*, with its explicit misanalogy to nature and its call for elimination and sterilization of the supposedly unfit:

> The fight for daily bread [in Nature] makes all those succumb who are weak, sickly and less determined. . . . The fight is always a means for the promotion of the species' health and force of resistance, and thus a cause for its development to a higher level. If it were different, every further development towards higher levels would stop, and rather the contrary would happen. For, since according to numbers, the inferior element always outweighs the superior element, under the same preservation of life and under the same propagating possibilities, the inferior element would increase so much more rapidly that finally the best element would be forced to step into the background, if no correction of this condition were carried out. But just this is done by Nature, by subjecting the weaker part to such difficult living conditions that even by this the number is restricted, and finally by preventing the remainder, without choice, from increasing [did Eichmann have this passage in mind when he advocated the same two-step process for the final solution: starve to a remnant by "difficult living conditions," then kill the rest?]. . . . Man, by trying to resist this iron logic of Nature, becomes entangled in a fight against the principles to which alone he, too, owes his existence as a human being. Thus his attack is bound to lead to his own doom.

A scientist's best defense against such misappropriation lies in a combination that may seem to mix two disparate traits—vigilance and humility. Vigilance in combating misuses that threaten effectiveness (you don't have to go after every

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kook who writes a letter to the local newspaper—time doesn't permit—but how can we distinguish the young Hitler from "just another nut"?). Humility in recognizing that science does not, and cannot in principle, find answers to moral questions. A popular linguistic construction of late would have us believe that morality comes packaged as a kind of "fiber"—as though one might measure its strength or pour it out of a cereal box prominently labeled (by exacting laboratory standards) with precise content and contribution to minimal daily requirements!

Science can supply information as input to a moral decision, but the ethical realm of "oughts" cannot be logically specified by the factual "is" of the natural world—the only aspect of reality that science can adjudicate. As a scientist, I can refute the stated genetic rationale for Nazi evil and nonsense. But when I stand against their policy, I must do so as everyman—as a human being. For I win my right to engage moral issues by my membership in *Homo sapiens*—a right vested in absolutely every human being who has ever graced this earth, and a responsibility for all who are able.

If we ever grasped this deepest sense of a truly universal community—the equal worth of all as expressions of a single entity, the species *Homo sapiens*, whatever our individual misfortunes or disabilities—then Isaiah's vision could be realized, and our human wolves would dwell in peace with lambs, for "they shall not hurt nor destroy in all my holy mountain." We are freighted with heritage, both biological and cultural, that grants us capacity both for infinite sweetness and for unspeakable evil. What is morality but the struggle to harness the first and suppress the second? Darwin's soul mate, the great American born on the very same day, said much the same in famous words of his first inaugural address in March 1861, when he still hoped to spare the nation from the horrors of Civil War. Lincoln asked us to remember the former unity of North and South and to avoid destruction by applying our better nature to this memory. Let us extend his hope to all bodies of the single human species:

> The mystic chords of memory, stretching from every battlefield and patriot grave to every living heart and hearthstone all over this broad land, will yet swell the chorus of the Union when again touched, as surely they will be, by the better angels of our nature.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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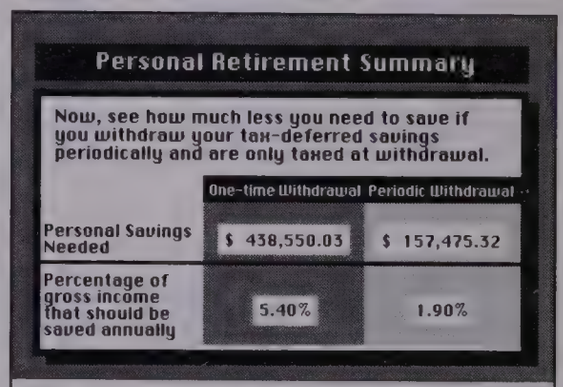
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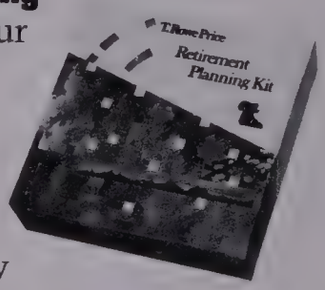

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No Fooling

Will the real ethnologists please stand up

by Roger L. Welsch

I'd like to consider a variation of the old chicken-and-egg quandary: which came first—the ethnologist or the comedian? I understand that the original version of that great problem of modern science—the primogeniture of the chicken and the egg—has already been answered pretty much to everyone's satisfaction. I think I read it in Stephen Jay Gould's column: Birds are descendants of dinosaurs and dinosaurs laid eggs, therefore the egg came first. In fact, lots of eggs came first. Time to move on, and I'm just the guy to make the move.

Fifty years ago Margaret Mead, Hortense Powdermaker (no kidding), and other ethnologists sat quietly in corners of humble houses and huts all around the world, observing, taking notes, and being as unobtrusive as they could be, considering that they came from a different world, were usually of a different race, embraced alien thoughts, did utterly unthinkable things, and were crouching in someone else's bedroom. Today that role is filled by stand-up comedians. (I don't know what happened to the ethnologists; a lot of them became folklorists, I think, and some were retooled as accountants. The smart ones became comedians themselves.)

Now and then I have the opportunity to spend a night in a big-city hotel that has cable television, and whenever I can, I watch the VH-1, Showtime, and Home Box Office channels. A good part of the programming on those channels consists of stand-up comedians paying their dues, doing their routines in nightclubs that apparently specialize in stand-up comedy. Indeed, the men and women doing stand-up comedy on television have already paid a lot of dues, and their appearance at the Comedy Shop, the Improv, the Funny Firm, and all the other *boîtes* that provide a stage for comedy is for these performers a main event rather than a preliminary.

Which is to say, these are not struggling amateurs à la *Punch Line,* Sally Field's movie about stand-up comedy, but performers equivalent to an assistant professor in anthropology with a leg up on tenure and specializing in the Tlingit potlatch or Uzbek rites of passage. They even work with the same sort of material—economics, politics, kinship and caste systems, rites of passage, religion, foodways, material culture, courtship. It's getting so you can't tell the difference between an anthropology department catalog and television listings for "Comedy Tuesday."

The impetus for the transmutation of ethnology probably came simultaneously from two directions: Anthropologists increasingly turned their eye from exotic, distant peoples and lands and began to look instead at their friends and neighbors—Mead and Powdermaker are a couple of good examples of that change of focus—and comedians moved from invention to observation.

My suspicion is that it was George Carlin, the most important American ethnologist since Mead, who initiated the metamorphosis of humor. Carlin's work dwarfs almost everything done in social anthropology before him; for example, there is no clearer explanation of the hierarchy of material culture than his hilarious monologue on a traveler reducing his luggage, step by step, tour by tour, to an ever smaller, ever more refined inventory.

I heard the routine on Dick Cavett's radio series, "The Comedy Show," while I was driving somewhere. Carlin described the traveler's mental process as he decides what *stuff*—Carlin spat out the word as if to emphasize what this essay was all about—to take with him on a vacation to a tropical paradise—Hawaii, I think. I laughed, not because Carlin's thesis was absurd, but rather because it captured reality so well, and reality is so ridiculous. I realized I go through the process he described every time I pack a suitcase; it was as if Carlin had watched me from . . . from a corner of my bedroom. I glanced at my speedometer. Jeez, I was driving thirty-two miles an hour on the freeway! I brought my car back up to speed.

When Carlin's tourist arrives at his destination, he unpacks his *stuff* in his hotel room and prepares for a short side trip to a neighboring island. He can't take all his *stuff* in his small overnight case, so he has to make decisions again about what *stuff* to take along this time. Then he has to decide which of his *stuff* he parks in the overnight lodging's bathroom, and which *stuff* to pack in his pockets for the beach. Every step in the elimination of vital *stuff* required agonizing considerations, and Carlin described each in detail. Carlin had read my mind. I looked down. I was doing eighty-five and passing semis.

The techniques with which stand-up comedians present their observations and conclusions about our behavior constitute the methodology of their science. Comedians (the scientists) study culture (the things they joke about) with an analytical tool (the things we laugh at, or humor). The corpus and its analysis is right there in front of all of us; the comedians are the scholars who know how to bring the method to the material and offer us insightful analyses, standing on a stage instead of at a podium, laughing instead of droning, in front of revelers rather than sleeping students.

(Caution! Do not confuse the term *comedian* with *humorist*. The difference between a comedian and a humorist is about 500 decibels of laughter per punch line and a lot more pay per month. Humorists show up on educational television; comedians perform on VH-1 or HBO. Humorists get more respect than comedians, but comedians get more money because they are crazier and therefore more dangerous to social and political stability—

they are paid more by way of reminding them of whom they depend on for their bread and its butter. Mark Russell and Garrison Keillor are humorists. Theirs is the stuff of literature. They get invited to the White House. They are evenhanded in the distribution of their ridicule, so only a hopelessly poor sport could be offended by their material. But comedians! Do you think Judy Tenuda, Robin Williams, and Jonathan Winters get many invitations to the White House?)

The ethnologists of the Improv, Funny Firm, and Comedy Shop variety laugh first of all and best of all at themselves and at that which is in all of us, including them. Whole routines focus on the black rubber bars we put between our groceries as we feed them onto the supermarket conveyor: "Have you ever noticed that no one—no one!—ever violates the sanctity of those little black rubber bars? Why don't we just buy enough of them to put between countries like Kuwait and Iraq or Syria and Israel? Everyone would keep his groceries—and armies—on his side of the rubber bar!" "Have you ever noticed how uncertain men are these days when they start to open a door for a woman? Is she going to thank him or call him a sexist pig?" "Who puts all those pins in new shirts anyway? And why?" "Have you ever noticed how people answer the telephone? 'Hello?' What's that? It says nothing at all. Why not just grunt?" The new American humor finds its source in the idiosyncrasies of what we all do on an everyday basis. Ethnologists like George Carlin help us stand aside from ourselves and look back at our own behavior . . . and laugh at it.

They collect, analyze, and present field-gathered data—just like the anthropologists of the old school. Folk humor, of course, exists without a need for experts (comedians) and is usually well ahead of them. Sometimes we are appalled at what appears to be the insensitivity of "reaction humor"—for example, the jokes that appeared within hours of the *Challenger* disaster or the Thomas-Hill Supreme Court hearings. But let's face it: we laugh at those things that bother us, disturb our tranquility, even threaten us—and that sort of information is precisely what the evening news tells us.

My son, Chris, is currently teaching in Bratislava, Czechoslovakia, a nation threatened by the tattered remnants of what was even originally a shabby industrial complex. The butt of Bratislavan humor, Chris reports, is the Skoda, a tinny car manufactured right outside of town. Why does the Skoda have a back window heater? To keep your hands warm while you're pushing it. A fellow goes into a parts store and asks, "Can I get a gas cap for a Skoda?" and the guy behind the counter says, "Seems like a fair trade to me." The problem of the Czechs in Bratislava is the Skoda; but they can laugh at it.

When the bank in our little village of Dannebrog, Nebraska, failed, there was a very real chance that our community would not survive. I was out of town and called my friend Eric. "How is everyone in town taking it, Eric?" I asked gravely.

"Well, Rog, the biggest problem," he deadpanned, "is that since there are no two-story buildings in town, everyone's trying to kill themselves by jumping off the curb!"

Our fear was never the same. Couldn't be. Once you've laughed at something—even something as enormous as disease, murder, death, disaster, horror, or bank failures—you can never be quite as afraid of it again. That's why so many gods in so many religions laugh rather than growl or thunder at evil; if there is anything evil can't stand, it's being laughed at.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

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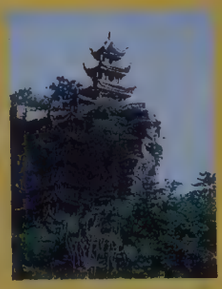

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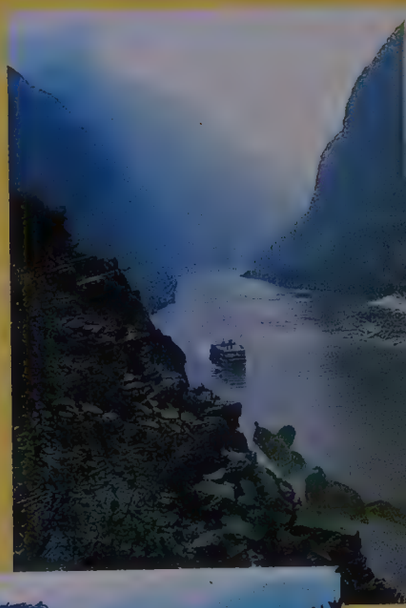

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"That Unmanned Wild Countrey"

Native Americans both conserved and transformed New World environments

by Samuel M. Wilson

In the mid-1600s, the English settlers who had gained a foothold along the eastern seaboard of North America began to make a profit by growing Native American tobacco and selling it in European markets. This kind of enterprise demanded farmland, and even more land was needed by the increasing tide of colonists arriving in the mid-Atlantic states and New England. But the land from Florida to Maine was occupied by American Indians—numbering in the hundreds of thousands—who lived in permanent villages, hunted wild game in well-defined hunting territories, and grew crops in fields that were shifted in a regular pattern as the fertility of the soil declined.

The English colonists came up with two justifications for taking the Native Americans' lands. First, they argued that colonists would civilize the Indians and "cover their naked miserie, with civill use of foode and cloathing." In royal charters given to the companies organizing the colonization, mention was always made of the obligation to bring Christianity to the "savages." The other part of the rationale was that Europeans could put the land to a "higher use," making it more productive by intensive cultivation and by bringing in livestock. In 1625 Samuel Purchas argued that God did not intend for the land to remain as "that unmanned wild Countrey, which [the savages] range rather than inhabite."

In early laws in Virginia and Massachusetts, and in many recorded sermons, biblical passages were quoted as justification for the appropriation of land: "Ask of me, and I shall give thee the heathen for thine inheritance, and the uttermost parts of the earth for thy possession" (Psalms 2:8); and, "Whosoever, therefore, resisteth the power, resisteth the ordinance of God; and they that resist shall receive to themselves damnation" (Romans 13:2). A contemporary satirist (who wisely chose to remain anonymous) put it succinctly in a supposed summary of a Puritan town meeting: "Voted, that the earth is the Lord's and the fulness thereof; Voted, that the earth is given to the Saints; Voted, that we are the Saints."

The idea that land could be taken if it was not being used as the English would use it, or if the people on it were "uncivilized" or not of the proper religion, was not new. In the late 1500s, the English had conquered parts of Ireland on the same pretext. In 1978, Irish historian Nicholas Canny noted that even though England and Ireland were similar in terms of religion and land use, the Irish quickly came to be viewed as uncivilized people, even as cannibals (a charge that proved effective in mobilizing force against Indians as well): "Once it was established that the Irish were pagans, the first logical step had been taken toward declaring them barbarians."

The idea that Europeans might put the land to higher use required downplaying how the native people were using it. This was somewhat problematic because the land the settlers desired most was the best land, that which the Indians had already cleared for their own crops of beans, corn, pumpkins, squash, and tobacco. The English were able, however, to construct an image of the Indians as nomadic hunters who did not change the landscape. According to historian Francis Jennings, when the lawyer John Winthrop took control of an English company in the Atlantic colonies in 1630, he declared that

> most land in America was *vacuum domicilium*—i.e., legally "waste"—because the Indians had not "subdued" it by methods recognized in English law and therefore had no "natural" right to it; the alternative of "civil" right was impossible for Indians because they did not have civil government. In operational terms civil government meant European government [*The Invasion of America*, 1976].

Later, in the eighteenth century, Enlightenment thinkers such as Rousseau saw the Indians as "noble savages" who lived at one with nature, without want, greed, or possessiveness, untainted by contact with civilization. The eloquent and influential nineteenth-century historian Francis Parkman believed that the Indian was "a true child of the forest and the desert. The wastes and solitudes of nature are his congenial home." In this way, the Indians were nearly defined out of existence, allowing frontier historian Frederick Jackson Turner, in 1920, to say that the West had been "free land" and Walter Prescott Webb, in 1931, to refer to it as "land free to be taken."

But New World people had changed the landscape, often in ways the European colonists did not appreciate. Along the east coast of North America, the lands that the English sought for tobacco cultivation had been planted for thousands of years. As fertility declined in some fields, the Indians opened up others, leaving the older ones to lie fallow. Later they might return to previously used fields, whose overgrowth of brush and small trees was easier to clear than climax forest. By the time the colonists arrived, the eastern woodlands had become a mosaic of Indian fields, some in use, some overgrown with brush, some nearly forests again.

Fire was a useful tool for renovating farming plots: it not only cleared the undergrowth but it also returned nutrients from the vegetation to the soil. Indians used fire widely in eastern North America to change the nature of the forests. English settlers recorded a marked shift in the forest vegetation after the Indians retreated farther west. At first the forest was described as "parklands," with little vegetation at ground level. After the Indians died or moved away, the Europeans began to describe the forest as dense and scrubby, with impenetrable thickets of vegetation beneath the woodland canopy.

Native Americans had used controlled burning to limit the growth of the understory, thus making it easier to hunt, collect wild foods such as hickory nuts and acorns, and cultivate the land. They knew that deer and the other animals they hunted thrived on plants that grew after the forest floor was burned. Prehistoric land-use patterns can be reconstructed through archeological excavation and the analysis of preserved plant pollen. Archeologist Jefferson Chapman and paleoecologists Hazel Delcourt and Paul Delcourt, for example, have charted 10,000 years of human impact on the environments of eastern Tennessee (*see*

"Strawberry Fields, Almost Forever," *Natural History,* September 1989).

Farther west, Native Americans used fires to turn forests into grasslands and, in drier areas, to keep prairies from becoming chaparral or scrub deserts. In "Indian Fires of Spring" (*Natural History,* January 1980), archeologist Henry Lewis described how, for millennia, the Indians modified landscapes in Alberta, and how present-day environmental agencies are rediscovering the advantages of controlled burning. The catastrophic fires in Yellowstone National Park in the summer of 1988 showed that fire is an inherent part of the forest ecosystem, without which some species cannot survive or reproduce. They also showed the dangers of suppressing natural fires for decades.

In what is now the southwestern United States and northern Mexico, people rerouted the flow of rivers to create environments capable of supporting large populations. For example, in about A.D. 1000, Hohokam Indians built an elaborate system of canals and irrigated fields in the floodplains of the Gila and Salt rivers (south of modern Phoenix). On a larger scale, Middle and South American peoples, such as the Aztecs, the Incas, and their predecessors, transformed landscapes with thousands of miles of canals and extensive drained or irrigated fields.

The possibility that early Native Americans were responsible for the extinction of the large animals of the Western Hemisphere has been hotly debated by archeologists and vertebrate paleontologists for the past thirty years. Many of the animals that were around at the end of the last glaciation 12,000 years ago—mastodons, giant sloths, camels, giant beavers, and many more—disappeared soon after the climate warmed. The weapons and butchering tools found with the bones of these animals make it hard to argue that humans played no role in these extinctions. In the Caribbean the extermination of such species as giant flightless owls can be more closely tied to the arrival of the first humans. Like the giant flightless birds of New Zealand, the owls had no defenses against human predation.

While some scholars have documented the effect New World peoples had on their environment, others have sought to cast them as primitive conservationists, people who knew the inner workings of ecosystems and lived without changing them. This view, which emerged in the nineteenth century, gained widespread favor in this century. For example, in "Aboriginal Conservators," a 1938 article in *Birdlore,* anthropologist Frank Speck wrote:

> Do uncivilized tribes know the virtues of conservation? The question would seem to require an answer in the negative in view of what is generally believed to represent the intelligence standard of peoples who have not reached the status of advanced civilization. Surprising though it may seem, the answer is, nevertheless, in the affirmative so far as the eastern and northern forests of the continent are concerned.

More recently, former Secretary of the Interior Stewart L. Udall declared that "the Indians were, in truth, the pioneer ecologists of this country." And a television spot makes use of this imagery: it shows an unidentified American Indian wearing a strange mixture of plains and woodland clothes, paddling a canoe (from yet another area), and beholding modern pollution with tears in his eyes.

People who call Native Americans conservationists probably intend this as a compliment to their sophistication. The ability to wreak havoc on the environment is no longer regarded as a measure of civilization. But this compliment retains a note of condescension, assuming that Europeans had the ability to subdue the land, even if unwisely, while native peoples merely adapted to it, finding ways of surviving without changing things. In other words, for the Indians, environments shaped cultures, but for Europeans, cultures shaped environments.

The disdainful argument that Native Americans did not destroy the land simply because they did not have the means to do so was put forward in 1968 by historian Peter Farb, who wrote:

> If the Northern Athabaskan and Northern Algonkian Indians husbanded the land and its wildlife in primeval times, it was only because they lacked both the technology to kill very many animals and the market for so many furs. But once White traders entered the picture, supplying the Indians with efficient guns and an apparently limitless market for furs beyond the Seas, the Indians went on an orgy of destruction [*Man's Rise to Civilization as Shown by the Indians of North America from Primeval Times to the Coming of the Industrial State*].

This orgy of destruction, however, was introduced by European Americans; the Indian participation is strong evidence that the traditional cultural values of northern forest peoples had eroded by the eighteenth century. Historian Calvin Martin's *Keepers of the Game* (1978) provides a glimpse of the cultural mechanisms that prevented overexploitation even during the fur trade. "The single most important deterrent to excessive hunting . . . ," he argues,

> was the fear of spiritual reprisal for indiscreet slaughter. Prior to European influence, these Indians of the Canadian forest were on amicable terms with the spirits of the game, including the game "bosses," or keepers of the game, and it was the vivid, daily awareness of this courteous relationship which more than anything else precluded overkill.

Throughout North America, a similar logic held. As the Ojibwa writer P. Jones observed of his own people in 1861, "They suppose that all animals, fish, trees, stones, etc., are endued with immortal spirits and that they possess supernatural power to punish any one who may dare despise or make any unnecessary waste of them."

Native Americans have been conceived of in many ways, as both savage and noble. The latest stereotype, as "ecological Indians," oversimplifies their interaction with their environment. The important lesson they offer is that they changed the New World continents in ways that made the land more productive, and yet they carefully avoided the destruction of the ecosystems of the Americas.

Samuel M. Wilson teaches anthropology at the University of Texas at Austin.

Our Phantom Children

Most fertilized human embryos die before birth. Some seemingly lethal genes, like those for juvenile-onset diabetes, may persist by helping us past that risk of miscarriage

by Jared Diamond

My maternal grandmother died when I was seven years old—old enough to remember her but still too young to understand her life story. I recall my surprise on being told that Grandma had been so grief-stricken on the death of an infant daughter (one of my mother's older sisters) that she scarcely smiled for a year afterward. Why, I wondered as a child, was someone with eight surviving children so devastated by the death of a ninth?

Forty years later, the answer became obvious to me when I nearly lost one of my own children. Of course Grandma could never forget, any more than can any other parent who outlives a child. Decades later, the bereaved parent still wonders, what would my lost ghost be like now, if he or she had survived?

Such questioning must have pervaded life in past centuries, when infant mortality was high. Of Johann Sebastian Bach's many children, ten died in infancy, as did ten of Schubert's thirteen siblings. As has often been pointed out, Bach's frequent bereavements may have contributed to the preoccupation with death in so much of his music. Four of Bach's surviving children became composers, although none quite matched their father's genius. Was there a potentially greater musical genius among those of Bach's children and Schubert's siblings who died as infants?

Today, when most of us survive to old age, premature death is considered an exceptional tragedy. In reality, that's true only if you define "us" as "those of us who survive to be born." In fact, the combined risk of all postnatal premature human deaths pales before the risk of death through miscarriage. Of pregnancies clearly recognized by the mother, only 15 percent end in miscarriage. However, modern hormonal tests can detect many other pregnancies that terminate within a couple of weeks, indicating a total miscarriage rate of about 50 percent rather than 15 percent. Such early miscarriages either escape the mother's attention entirely or express themselves only as a slightly strange sensation or slightly late menstrual period. Outcomes of attempted artificial fertilizations of ova within the fallopian tubes suggest that still more embryos are lost even before implantation, adding up to a total loss rate as high as 80 percent.

As a result of all this prenatal mortality, each of our recognized children is actually the lucky survivor of a set of phantoms, most of whom die before birth. Each of us, too, is the survivor of a set of otherwise unknown siblings. Look now at your children or siblings and see how different each is from the others. What sort of people would those lost phantoms have turned out to be?

Darwin taught us that whenever many die and few survive, genetic adaptations favoring survival automatically become selected. In previous columns I have argued that many of our genetic adaptations have been acquired at a price. That is, genes protecting us against widespread dangers often prove to expose us to different, rarer dangers. For example, the sickle-cell gene protects many Africans against the nearly ubiquitous risk of malaria, while condemning a few Africans, so-called homozygotes (those who have inherited the gene from both parents), to the risk of sickle-cell disease (*see* "Blood, Genes, and Malaria," February 1989). Other, more speculative examples of genetic protection at a price involve the genes for Tay-Sachs disease, cystic fibrosis, and hypertension, which curse some individuals with those afflictions but may protect many more against tuberculosis, bacterial diarrheas, and salt loss, respectively (*see* "The Saltshaker's Curse," October 1991). Evidently, nature hasn't been able to design all our selected adaptations as unmixed blessings; we've often had to settle for blessings that merely outweigh a new curse.

By this logic, we might be expected to have evolved some genetic adaptations that protect us against miscarriage while exposing us to new postnatal curses. From the evolutionary point of view of a fertilized embryo, it's worth paying a big price to reduce the risk of miscarriage, since the embryo's entire child-bearing career still lies ahead, and since miscarriage may be the biggest single cause of human death—if one counts fertilized embryos as human. Despite the good reasons why prenatal selection should be important, virtually all discussions of evolution since Darwin have instead focused exclusively on postnatal selection. Prenatal selection is a plausible, possibly pervasive, but hard-to-detect phenomenon in search of even a single concrete example.

In this piece I'll discuss the most likely candidate, the genes of juvenile-onset (so-called type I) diabetes. As Constance Vadheim, Jerome Rotter, and their colleagues at Cedars-Sinai Medical Center in Los Angeles have argued, those seemingly lethal genes may persist by helping fetuses survive the dangers of gestation while exposing some of the fetuses thereby saved to the risk of diabetes after birth.

You may recall that the more common form of diabetes is adult-onset (so-called type II) diabetes, whose evolution I discussed in my most recent column ("Sweet Death," February 1992). Like adult-onset

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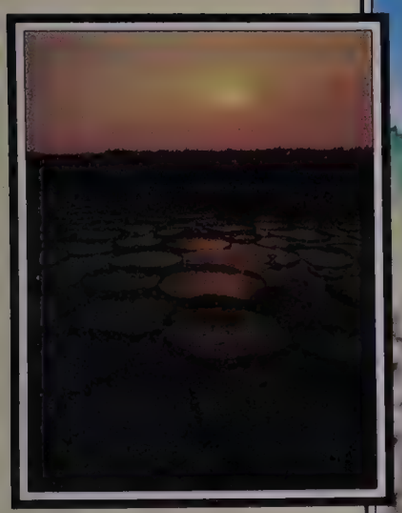

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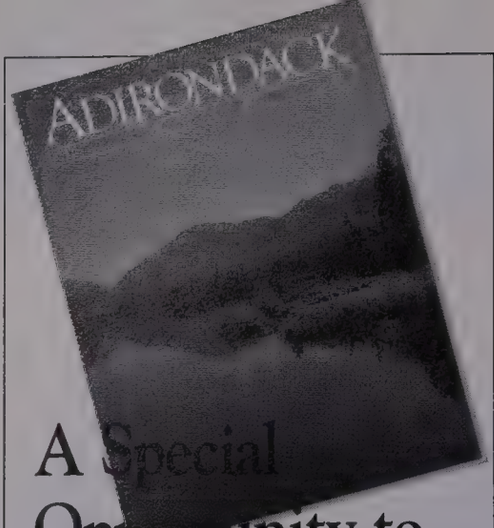

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diabetes, juvenile-onset diabetes involves deranged control of our blood glucose concentration, leading in the absence of medical treatment toward kidney and nerve damage, heart disease, stroke, and blindness. However, the two forms of diabetes differ in the mechanisms responsible for the disorder. In the case of adult-onset diabetes, derangement arises from abnormal resistance of glucose-absorbing tissues to the hormone insulin, which regulates tissue glucose uptake. As the term *adult-onset* implies, that common form of diabetes typically develops after age forty. Since the pancreas's ability to make insulin usually remains intact, disease symptoms can often be controlled by diet and weight loss alone.

In contrast, juvenile-onset diabetes involves destruction of those pancreatic cells (the so-called beta cells) that make insulin. Until insulin was isolated and became available for treatment in the 1920s, juvenile-onset diabetics were condemned to die before adulthood. Today they regularly reach adulthood but remain absolutely dependent on daily insulin injections for survival.

Paradoxically, the body of a juvenile-onset diabetic is programmed to destroy its own beta cells. The culprit is our immune system, whose normal function is to destroy foreign invaders rather than ourselves. Thus, juvenile-onset diabetes belongs to the class of illnesses known as autoimmune diseases, in which our immune system suicidally targets one of our tissues. The diabetic symptoms of weight loss, hunger, thirst, and profuse urine appear to come on suddenly, typically around puberty. In fact, the disaster has been brewing for months or years, as revealed by the presence of antibodies against the beta cells. Apparently, some triggering attack on these cells, by rubella virus, for instance, exposes their antigens to the immune system, leading to progressive destruction of the cells by an autoimmune reaction. Only when about 90 percent of the cells' capacity for insulin synthesis has been destroyed do diabetic symptoms manifest themselves.

Obviously, most of us go through life with our immune system doing only what it is supposed to do and not destroying our beta cells. The reasons that about 1 in every 300 Americans develops juvenile-onset diabetes (which I shall henceforth refer to just as diabetes, for short) are complex. In the first place, both genetic and environmental factors are involved. This is clear because about 36 percent of the identical twins of diabetics, but only 5 or 10 percent of fraternal (nonidentical) twins of diabetics, develop the disease. If the disease were purely genetic, identical twins would always either contract or escape diabetes. Thus, genes alone can't guarantee diabetes; something else is required, such as a viral infection or a chance event in immune system development. On the other hand, if the disease were purely environmental, identical and fraternal twins, of the same age and sharing the same environment, would face similar risks. The much higher risk of shared diabetes in identical twins (who share 100 percent of their genes) than in fraternal twins (who share only 50 percent of their genes) thus points to some genetic component.

In the second place, that genetic component itself is complex. Simple genetic diseases like Tay-Sachs disease involve a single gene; a defect in that gene causes the disease, regardless of the rest of one's genetic makeup. In contrast, diabetes arises from interactions between several different genes, spread over several chromosomes. The most important of those diabetes-predisposing genes specify components of our immune system termed HLAs, standing for human leukocyte antigens. HLAs are cell-surface proteins that play a role in the immune system's ability to recognize and destroy foreign antigens, such as those on the surface of invading microbes. In addition, foreign HLAs themselves, such as those on another person's tissues, trigger an immune response that causes us to reject an attempted graft or transplant of that tissue. That is why, if you need a skin graft or kidney transplant, your HLAs will be compared with those of prospective donors to be sure that they are compatible, as is most likely to be true if the donor is your parent or sibling.

In autoimmune diseases such as juvenile-onset diabetes, HLAs misbehave, and they mark for destruction not just foreign antigens but also some of the body's own antigens. In the case of diabetes, genetic analyses have shown strong correlations between the risk of diabetes and the form of a particular HLA gene termed HLA-DR. Among the various forms, or alleles, of the DR gene, DR3 and DR4 show the highest correlation with development of diabetes: 95 percent of diabetic patients carry DR3, DR4, or both. These two alleles appear to contribute in different ways to the risk of diabetes, so that people bearing both alleles together are at much higher risk than people bearing either one alone. In particular, DR3 predisposes to autoimmune diseases in general, while DR4 is specifically associated with autoimmune response to pancreatic antigens.

I reiterate that DR3 and DR4 by them-

selves don't cause diabetes, whereas a defective Tay-Sachs gene by itself does cause Tay-Sachs disease. DR3 and DR4 are common alleles, and while most diabetics prove to carry them, the converse is not true: most people carrying DR3 and/or DR4 do not develop diabetes. Instead, if you carry those HLA alleles *and* you carry certain other non-HLA genes *and* you get infected by a predisposing virus, that *combination* of factors may result in diabetes.

Nevertheless, the obvious question still arises: Why, if DR3 and DR4 smooth the path to autoimmune suicide, weren't such nasty alleles eliminated by natural selection long ago? Before insulin became available for treatment, bearers of those alleles who developed diabetes would have died without reproducing, and the alleles would have declined in frequency from generation to generation. That outcome would be inevitable—unless (as we know to be true for the sickle-cell gene) DR3 and DR4 also had some separate beneficial effect that outweighed their negative effect and paradoxically led to improved survival. Hence the persistence of DR3 and DR4 obliges us to postulate that such a beneficial effect exists, awaiting discovery. What might that be?

Clues come from genetic studies by Vadheim and Rotter and their colleagues, partly confirmed by work of other scientists, although details are still in dispute. While exactly half of the gametes produced by parents carrying a single DR3 or DR4 allele should carry that allele, more than half of the children born to the parents actually carry the allele—suggesting that fetuses with the allele have improved chances of prenatal survival!

The basis for this remarkable conclusion is as follows. Recall that we carry most of our chromosomes and genes in two copies: one copy inherited from our mother; the other from our father. Now consider someone for whom one copy of the HLA-DR gene is the allele DR4, while the other copy isn't DR4. (In genetic terminology, that person is heterozygous for DR4.) Half of that person's gametes (eggs or sperm) should therefore carry the DR4 allele, while the remaining gametes would carry the non-DR4 allele. Thus, 50 percent of the person's children should inherit their parent's DR4 allele.

In a study of 107 families with at least one diabetic child, Vadheim and Rotter confirmed that simple expectation for transmission of the DR4 allele from mother to child. However, not 50 percent but 72 percent of children of heterozygous DR3 fathers received the father's DR4, while nearly 70 percent of children of heterozygous DR3 fathers *or* mothers received their parent's DR3. In short, by the time babies emerged at birth from their mother's womb, an unexpectedly high proportion of the babies carried DR3 or DR4. Conversely, a disproportionate number of gametes or fetuses bearing an allele other than DR3 or DR4 must have died before birth.

By now, *Natural History* readers who are sophisticated gamblers may have spotted a potential flaw in the argument as I have presented it. The 107 families selected were not a random sample of families with DR3 or DR4 heterozygous parents. Instead, the families were selected precisely because they had at least one diabetic child. But it is already well known that (juvenile-onset) diabetes is strongly associated with DR3 and DR4, and that diabetic children are disproportionately likely to carry those alleles. Doesn't that mean that the 107 families were in effect selected because they had already produced DR3 or DR4 children, so that the sample of children was inevitably enriched in DR3 or DR4 kids? That sounds like taking hundreds of pennies, flipping them repeatedly to count heads or tails, selecting 107 pennies that happened to produce a disproportion of heads, and concluding that pennies in general are loaded. So at least it seemed to two sets of scientists who read the analysis by Vadheim

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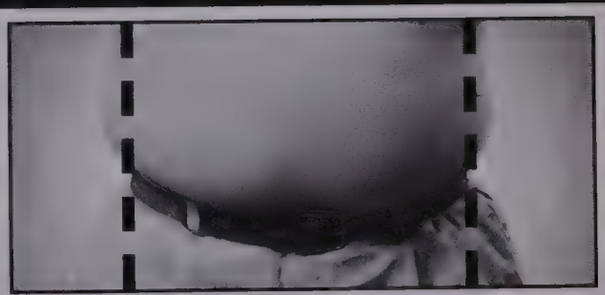

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and Rotter and their colleagues in the *New England Journal of Medicine*, and who wrote to the journal to criticize the analysis.

However, Vadheim and Rotter found that DR3 and DR4 were overrepresented not only in diabetic kids but also in their nondiabetic siblings. Biased sampling can't account for overrepresentation of DR3 and DR4 in nondiabetic kids—if anything, nondiabetic kids should have shown too few DR3 and DR4 alleles, because of the known association of those alleles with diabetes. In addition, reasoning based on biased selection of flipped pennies would apply equally to fathers and mothers and would fail to explain the finding of unexpectedly large numbers of babies bearing the father's (but not the mother's) DR4. That observation argues for a real phenomenon with a biological explanation, rather than biased data selection. In fact, it had already been recognized that diabetes is much more likely to be inherited from one's father than from one's mother: the risk of developing diabetes by the age of twenty is 6 percent versus only 1.3 percent for children of diabetic fathers and mothers, respectively. The mechanism of that difference may be the discovery, by the Vadheim-Rotter group, of preferential transmission of the diabetes-predisposing form of the allele DR4 from fathers.

Thus, heterozygous DR3 and DR4 parents in diabetic families produce gametes of which only 50 percent carry DR3 or DR4, but more than 50 percent of the eventually resulting babies carry DR3 or DR4. Some gametes carrying alleles other than DR3 or DR4 must have disappeared at some point along the pipeline. Did those gametes tend not to get fertilized, or did the resulting embryos tend to get aborted? The latter interpretation seems more likely. Couples consisting of a DR4 father and DR3 mother—the combination most likely to produce a diabetic child—also report a disproportionately high frequency of spontaneous abortions. In large families, the birth of each diabetic child leads to increased overrepresentation of DR3 and DR4 among younger siblings—as if each child predisposed to diabetes somehow immunizes the mother and makes nonpredisposed fetuses increasingly likely to miscarry in subsequent pregnancies.

These findings about diabetic families tie into a larger body of evidence about the role of the immune system in miscarriage. Since our immune system is expressly designed to expel foreign bodies, an obvious, still unsolved question is, why don't pregnant mothers routinely expel their fetus as just another foreign body? Paradoxically, it appears that a successful outcome of pregnancy may require the fetus to advertise itself as foreign and alert the mother, by displaying paternally derived antigens not shared by the mother. If those paternally inherited antigens happen to be identical to maternal antigens, miscarriage is especially likely. It is as if the fetus has to wave a red flag at the mother's immune system, with the message, "Yes, I'm actually different, but that's the way I'm supposed to be, so leave me alone!"

HLA signals evidently constitute part of this fetus-to-mother message. Couples sharing HLA alleles are prone to detectable spontaneous abortions because the fetus can't inherit from its father an HLA allele foreign to its mother. HLA sharing also predisposes to fetal losses so early that pregnancy escapes detection. For example, the Hutterites are a religious community especially attractive to geneticists, because they don't practice contraception and have an average completed family size of nine children. Carole Ober and her colleagues at the University of Chicago have enlisted the Hutterites for studies of human fertility unfettered by the constraints that most of us impose on ourselves. It turns out that Hutterite couples who share an HLA-DR antigen take longer to become pregnant (five versus two months), show a longer birth spacing

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between children (twenty-four versus nineteen months), and end up with a smaller completed family (6.5 instead of 9 kids) than do Hutterite couples not sharing an HLA-DR antigen. Evidently, sharing of antigens must be inhibiting fertilization, implantation, or early development of the embryo even before the mother knows that she is pregnant.

Thus, the immune system plays some role in the prenatal mortality that I mentioned at the outset. In some way not yet understood, in families predisposed to diabetes, fetuses with the DR3 or DR4 allele reduce their risk of miscarriage, compared with fetuses lacking these alleles.

Naturally, that would still do the DR3 or DR4 fetuses no good if they were guaranteed to die of diabetes in puberty. They wouldn't transmit their genes to any offspring, and those genes would disappear through natural selection. However, recall that your chance of escaping diabetes is an encouraging 65 percent even if your identical twin develops it, and is even higher if you merely carry the predisposing DR3 or DR4 allele. Thus, the DR3 or DR4 allele represents an evolutionarily balanced gamble: less risk of being miscarried, in return for more risk (but still a modest risk) of succumbing to diabetes later on. When Vadheim, Rotter, and their colleagues calculated the actual numbers, it turned out that the observed prenatal advantage was just sufficient to maintain the diabetes-predisposing genes at their observed frequencies in the face of the observed postnatal risk. The high risk of death before birth makes it certain that other cases of genes sustained by prenatal advantage will be discovered, whether or not the evidence for such a role in juvenile-onset diabetes proves valid.

Perhaps the concept of protection at a price may help us see some meaning in diabetes and other genetic diseases. We are all familiar with life's normal dangers, those awaiting us after birth. Yet life before birth is even more dangerous, proving fatal to most of us (most fertilized embryos, that is). The genes for juvenile-onset diabetes represent a bargain with the devil that natural selection has made for us, to improve our chances of passing that prenatal hurdle. Fortunately, the odds are stacked in our favor, and against our getting diabetes. If it weren't for those genes and others that offer prenatal protection, we ourselves, the living, might have joined the ranks of our phantom siblings who died before they could be born.

Jared Diamond studies evolutionary biology and teaches physiology at UCLA Medical School.

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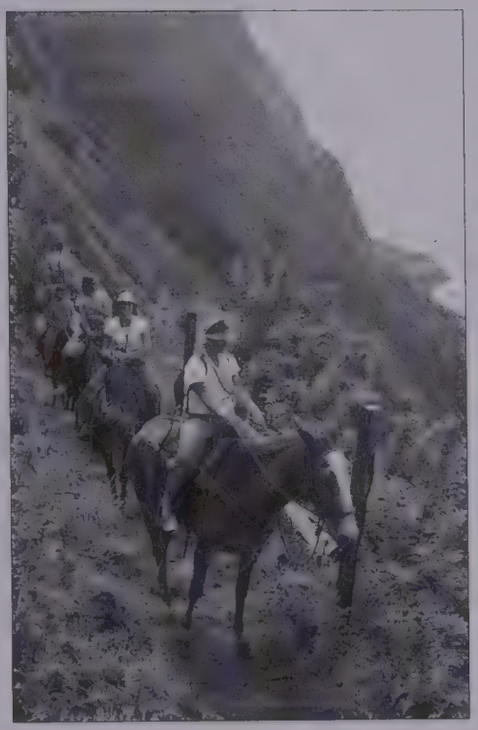

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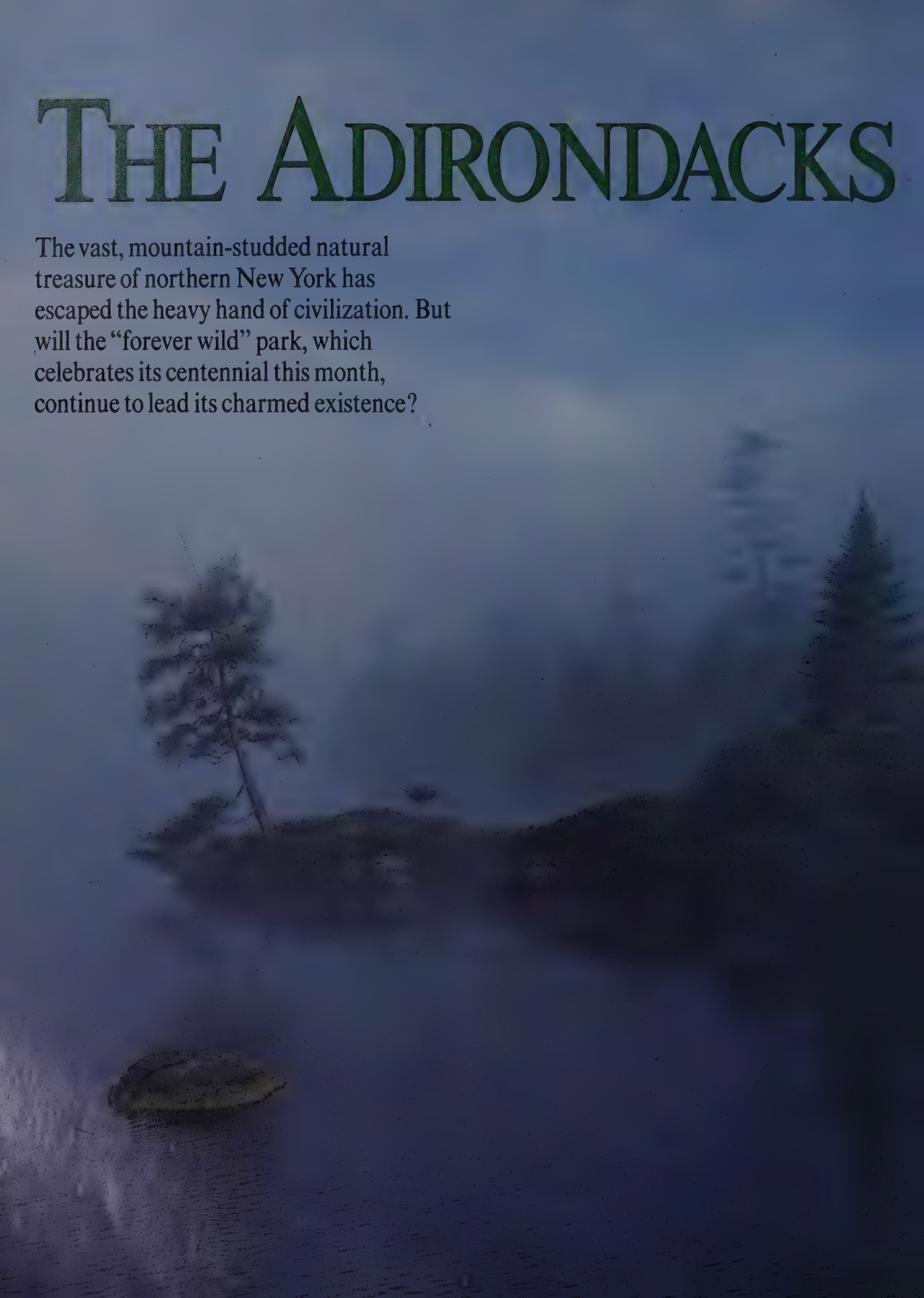
THE ADIRONDACKS

The vast, mountain-studded natural treasure of northern New York has escaped the heavy hand of civilization. But will the "forever wild" park, which celebrates its centennial this month, continue to lead its charmed existence?



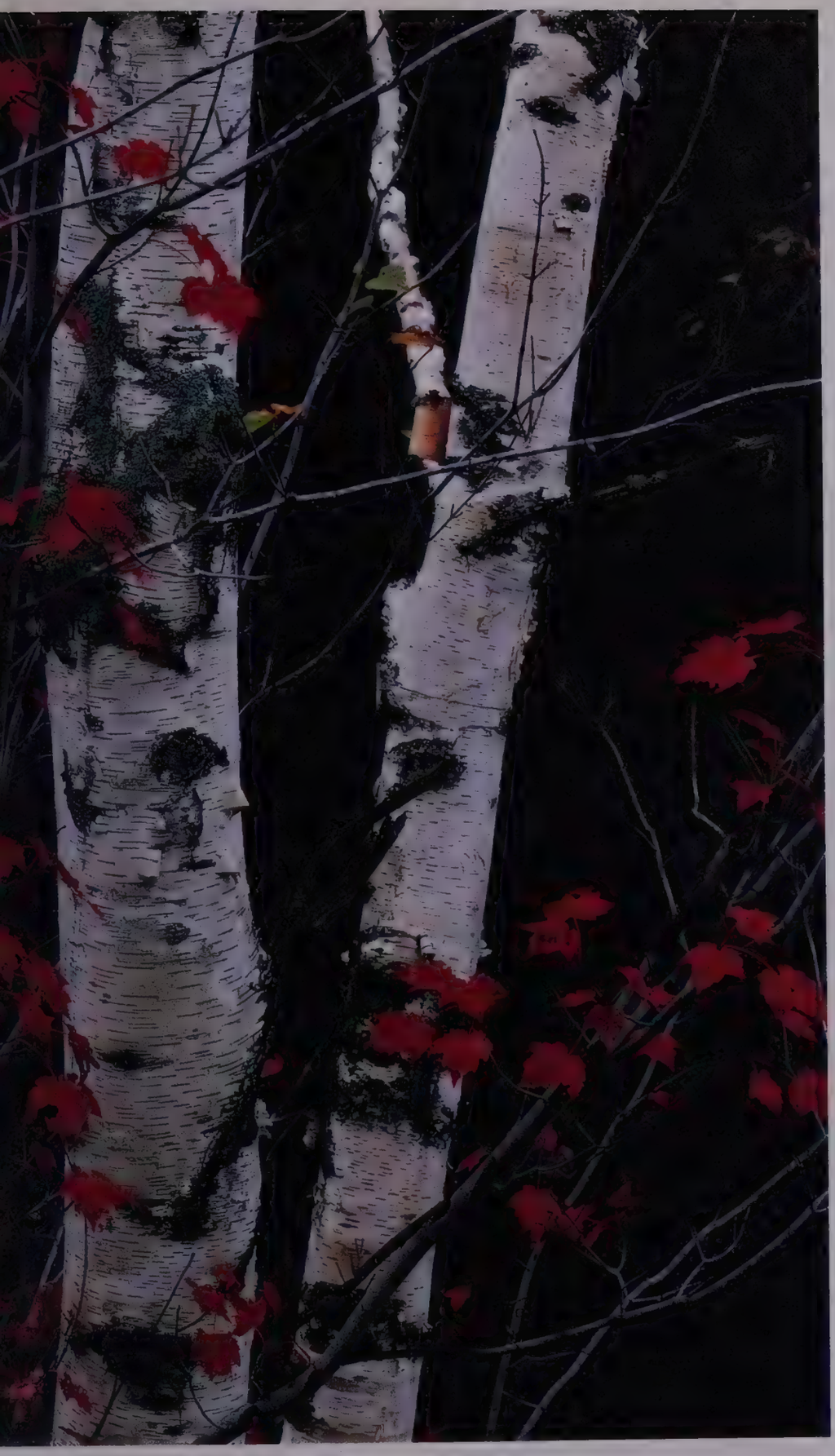
Little Indian Lake
Robert A. Lubeck

A Place Between Places

by Russell Banks

Bordered by the Champlain Valley in the east, by the Saint Lawrence watershed in the north, by the valley of the Hudson in the south, and by the gently rolling hills and valleys of New York State in the west, this 6,000,000-acre region of mountain, muskeg, marsh, and pond, this land of abbreviated summers and endless winters, this "howling wilderness," as the first white settlers called it, was from the beginning a kind of ultima Thule. In fact, it was not until late in the nineteenth century that it was properly mapped, long after the northwestern territories of Washington and Oregon had been charted. The Adirondack region is a true borderland, a place *between* places, which in a sense is what has preserved it more or less intact into the late twentieth century. It may also account for its continuing attraction for so many writers, artists, and philosophers, people whose lives depend for their meaning on standing slightly outside the world.

From the wood engravings that picture Champlain's tentative first encounter with North American wilderness to the svelte four-color ad inserts of Ralph Lauren, from the pages of James Fenimore Cooper to E. L. Doctorow's *Loon Lake,* from the transcendentalists' Philosophers' Camp to the U.S. Army's Fort Drum, the word *Adirondack* has been used over centuries to evoke a wide variety of images and meaning. It's not clear if the Algonquins used it first, to refer to the Iroquois who lived on those dark, rock-topped mountains and in birch and balsam-covered valleys, or vice versa, but in either case the word was translated into nineteenth-century English as "bark eater." It alluded, of course, not so much to the natives' diet of choice as to one of the more unpleasant consequences of their having been forced by hostile and more organized neighbors to reside in what everyone, Algonquin, Iroquois, European, and Yankee, regarded as an essentially uninhabitable region. A century or two later, after the Revolutionary War, the grateful Commander in Chief offered chunks of the region to his New England and New York soldiers as a veteran's benefit. Despite the undeniable beauty of the place—haunting mountain passes and waterfalls, splendid primeval forests, glittering chains of lakes, and abundant fish and game—there were very few takers. Too cold, too much snow and ice, too little arable soil, too many black flies and mosquitoes in spring and summer. Landless veterans preferred to pay a pretty price for Vermont acreage or simply moved west and south to homestead in Pennsylvania



Maple and birch along the Opalescent River
Carr Clifton

and Ohio. The Adirondacks they left to hunters, adventurers, hermits, and, in time, to bluff and hearty millionaire "campers" on seasonal safari, roughing it in their accustomed Victorian splendor.

The region is situated at the southern edge of Canada and the northern edge of the United States. Cut off from all the main waterways and canals, and in this century bypassed by interstate and thruway alike, it has always been too far from large cities and their suburbs to invite weekend tourists or casual visitors of any kind. Except for a few, relatively brief interludes in the nineteenth and early twentieth centuries, raw materials such as iron, lead, and semiprecious stones were more easily and cheaply obtained elsewhere (outside of lumber, perhaps, and even that industry has moved on in recent years to places like Georgia and Washington State). Bypassed, too, by both the aboveground and underground railways (escaping slaves slipped into Canada by way of the Hudson and Champlain valleys or crossed over at Rochester and Buffalo), the Adirondacks was not even one of those places that you had to cross to get to someplace else more important. You could always go around the area more easily than through it.

Ironically, then, the importance of the Adirondacks until recently may well have derived from its perceived *lack* of importance. Perhaps this is why there was so little resistance from the usual suspects when, a century ago this year, the New York State legislature created the Adirondack Park, proclaiming that the region was essential to the welfare of the whole state. Over the years, conservationists, year-round residents, and recreational visitors from downstate have managed to coexist peaceably. The few remaining mining operations were phased out, and the lumber barons gradually sold off their unused forestland. The delicate equilibrium held—at least until the 1980s, when inflationary land prices, the growing tourist industry, and a genuine housing shortage for native Adirondackers suddenly made that hundred-year-old balance downright precarious. Since then the fragility of the Adirondack ecosystem has been minimized, rationalized, and all but dismissed by developers, banks, and real estate interests. In fact, the legislation that created the park in 1892 probably could not be passed in 1992.

The Adirondacks is, after all, borderland, situated at the far edge of civilization and the near edge of wilderness, and therefore what happens here in the next ten or twenty years will have profound effects on both civilization and wilderness. As the novelist Doris Lessing has said, "Things change at the edges." And indeed they do, all the way in to the center. If we do not want them to change catastrophically for the worse, then we must hold the line at the borders. For what is happening now at the edges of the Adirondacks, where the old northeastern United States cities bump up against the howling wilderness, where, one might say, the City of Man meets the City of God, is very likely to be occurring soon at the edges everywhere in North America. If we do not hold the line here and now, then in future centuries, if the word *Adirondack* is used at all, it will refer in elegiac tones only to the beginning of the end of both our wilderness and our civilization. □

Tracing the Blue Line

by Philip G. Terrie

The Adirondack Park is a jewel, set aside as protected open space by one of the nation's most urban, industrialized states. Home to bears, moose, loons, and hundreds of other wild species (as well as 130,000 year-round human residents), the park contains alpine peaks, vast expanses of forest, crystalline lakes, and rivers you can still drink from. Yet the same era that preserved this treasure was rotten with corruption and environmental abuse. Cut-and-run loggers razed forests across the country, miners ripped minerals from the earth, cities and factories poured unspeakable waste into rivers and lakes. It was an age when opportunistic robber barons made millions by raping the land and stealing its resources.

So who saved this fragile and beautiful region? And why?

It's a long story, but we can start with George Perkins Marsh, a failed Vermont politician appointed by Abraham Lincoln to a consular post in Turkey. Shocked by the scarred landscape of the eastern Mediterranean, Marsh pondered the consequences of thousands of years of human abuse of the earth. He saw bare mountains that in historical times had been covered with lush forests, and he watched the rain and snowmelt, once held and slowly released by those forests, come flooding down the now lifeless slopes.

The result of Marsh's observations was *Man and Nature; or, Physical Geography as Modified by Human Action,* a lengthy, densely written, copiously documented technical treatise warning that if human beings didn't change their wasteful ways, their once hospitable world would turn to dust. Published in 1864, this seminal book quickly reached an international readership and is now hailed as a major fountainhead of the worldwide conservation movement; it also played a pivotal, although perhaps unanticipated, role in the creation of the Adirondack Park, which was signed into existence by New York governor Roswell P. Flower on May 20, 1892.

Marsh predicted that further "improvidence" would lead to "the deprivation, barbarism, and perhaps even extinction" of humanity itself, and he especially warned against cutting trees on steep slopes. Mountain forests controlled the runoff of rain and melting snow, and the result of denuded hillsides was catastrophic cycles of flood and drought in the valleys below. *Man and Nature* particularly caught the attention of New Yorkers, for it appeared just as loggers were swarming into the Adirondacks, eager to cut the region's billions of board feet of virgin pine and spruce.

Cut they did—with ruthless abandon—sending prodigious rivers of logs to bustling mill towns like Glens Falls. But the vast north country was big enough and wild enough to supply both logs and wilderness, at least for a while. And William H. H. Murray, a prominent Congregationalist minister from Boston, hit on a sure best seller when he described the delights of hunting and fishing while surrounded by "magnificent scenery which makes this wilderness to rival Switzerland." When Murray started camping in the Adirondacks during the Civil War, he found a rugged country barely touched by civilization. Except for a few villages and marginal farms and a scattering of mines, an area the size of Massachusetts was as wild and unknown as many parts of the West. The source of the Hudson River, Lake Tear of the Clouds, was unknown to map makers until 1872, and there is no evidence that Native Americans had ever inhabited this region.

Murray's *Adventures in the Wilderness; or, Camp-Life in the Adirondacks,* published in 1869, was an effervescent, breezy narrative of hunting and fishing exploits. It encouraged thousands of neophyte shooters and anglers to head for the Adirondacks, where, seduced by accounts of deer behind every tree and trout in every pool, they were quickly dubbed Murray's Fools, while the author himself was known for the rest of his life as Adirondack Murray. Most of the tourists searching for physical and spiritual revivification in nature found only black flies, a paucity of deer and trout, and a damp place to sleep, but the region had been discovered; from then on it was a popular retreat from the woes of an increasingly urban society. A few of Murray's Fools noticed they weren't the only people in the woods; the lumberjacks were there, too.

The man who brought together Marsh's environmental warnings and Murray's passion for the wilderness was a young Adirondack enthusiast named Verplanck Colvin. Born to a prosperous family in Albany in 1847, Colvin traded a position in his father's law office for a life dedicated to exploring and protecting the Adirondacks, where he eventually landed a job as a state surveyor (he was the discoverer of Lake Tear of the Clouds and could claim at least ten first ascents of major Adirondack peaks). Colvin's self-appointed mission was to spread the word throughout New York that if the depredations of uncontrolled logging were not stopped, the state would lose, in one dismal environmental catastrophe, two invaluable treasures: the watershed that guarded the flow of water in vital commercial arteries and the scenic, forested paradise that was the Adirondacks.

In 1870, Colvin, along with Adirondack hunter and hermit Alvah Dunning, made the first known ascent of Seward Mountain, a remote peak far from roads or even trails. Never one to miss a chance for advancing his favorite cause, Colvin wrote up an account of this expedition for the Albany Institute, later published by the New York State Museum. After two days of bushwhacking through a dense, nearly impenetrable forest, clambering over a fatiguing succession of ridges and false peaks, Colvin and Dunning reached the summit of Seward at eight o'clock on a chilly October morning:

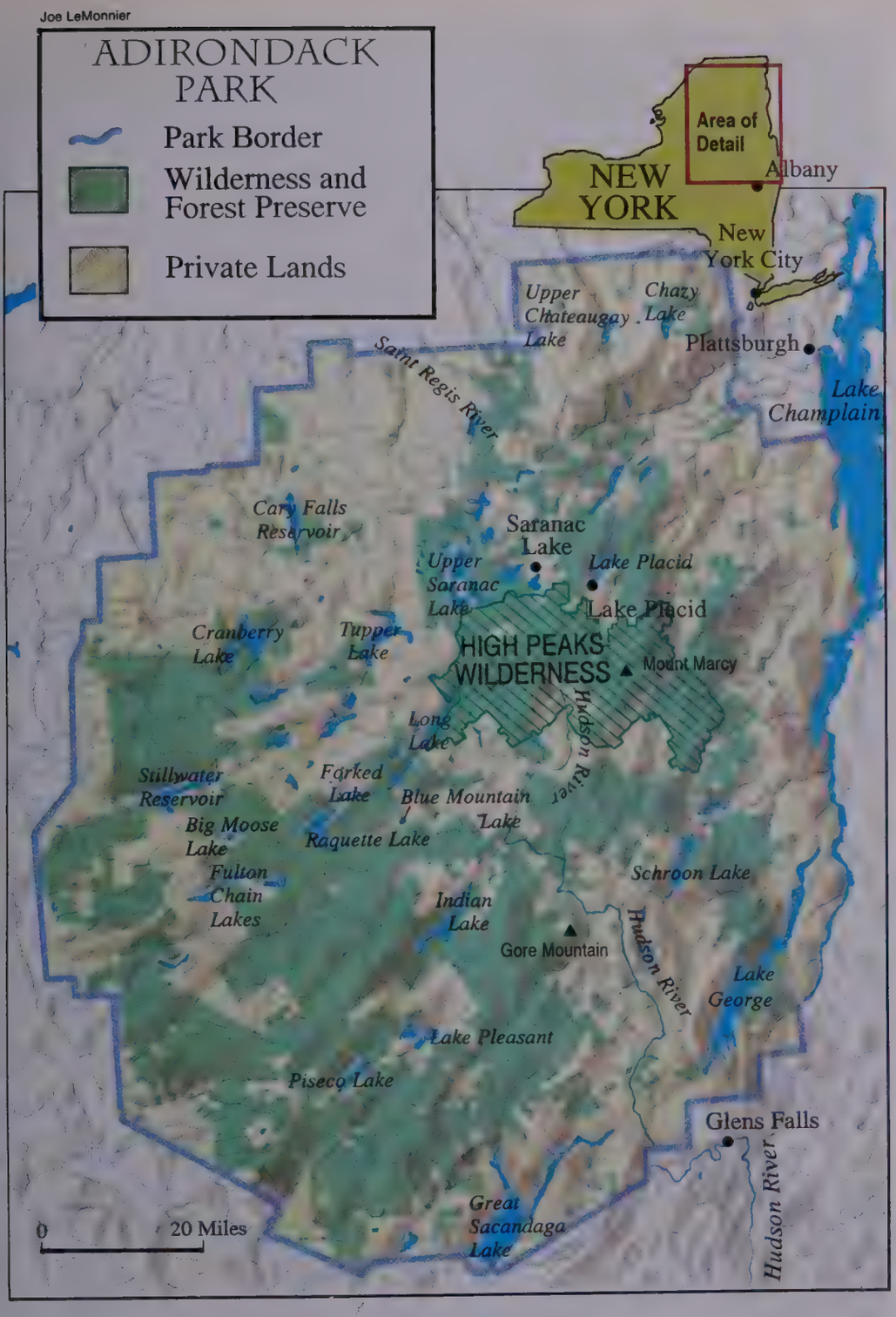
> The view hence was magnificent, yet differing from other of the loftier Adirondacks, in that no clearings were discernible; wilderness everywhere; lake on lake, river on river, mountain on mountain, numberless.

But Colvin was interested in more than spectacular scenery; in closing his narrative, he seized the opportunity to recount the imminent threats facing the region. He pointed out that the

> Adirondack wilderness contains the springs which are the sources of our principal rivers, and the feeders of the canals. Each summer the water supply for these rivers and canals is lessened, and commerce has suffered.

The cause for this was not hard to find. It was precisely the evil that George Marsh had warned against:

> The chopping and burning off of vast tracts of forest in the wilderness, which have hitherto sheltered from the sun's heat and evaporation the deep and lingering snows, the brooks and rivulets, and the thick, soaking, sphagnous moss which, at times knee-deep, half water and half plant, forms hanging lakes upon the mountain sides.



Weighing what could be done to save this forested treasure—so important both to commerce and to the spiritual and recreational future of New York State—Colvin came up with a portentous proposal: "The remedy for this is the creation of an Adirondack Park or *timber preserve*." Colvin was the first person to use the term "Adirondack Park" in print.

In 1872 the legislature set up a special commission, with Colvin acting as secretary, to look into Adirondack matters. Although the commission insisted that "the protection of a great portion of that forest from wanton destruction is absolutely and immediately required," for another decade New York couldn't raise the steam to move toward conservation. Meanwhile, the abuses of the forest continued unchecked, as logging companies bought land from the state at absurdly low prices, cut the marketable timber, and let the property revert to state ownership when the taxes were deliberately unpaid.

Meanwhile, transportation interests gloomily predicted the demise of New York's waterways, and hunters and anglers saw logging destroying their sport. Behind them all, Verplanck Colvin thundered endlessly that the last chance to preserve the Adirondacks was slipping away. One state official who listened to Colvin was Gov. Alonzo B. Cornell, who warned ominously in 1882 that if current logging practices did not change, "imminent danger will threaten.... The rainfalls will diminish, the springs and streams fail and unaccountable loss will ensue." Finally, in 1883, the legislature decided that state lands were no longer for sale.

Two years later, New York designated all public land in both the Adirondacks and the Catskills as the Forest Preserve and declared that it would be "forever kept as wild forest lands"—hence the expression "forever wild," applied ever since to the public domain in the state's two mountainous regions. The same law created a Forest Commission to manage the Forest Preserve. The trouble with the law was that the state didn't own enough of the land it wanted protected, especially in the Adirondacks, and nobody trusted the Forest Commission. Merchants who depended on a reliable watershed, sportsmen who wanted a place to hunt and fish, and doctors who believed the wholesome Adirondack air offered hope to people suffering from tuberculosis insisted on effective, regional conservation. The Forest Preserve law of 1885, which in fact permitted some logging on state land, was woefully short of providing the kind of protection that Colvin and many others demanded.

The inadequacies of the law were the subject of a series of muckraking articles appearing in the *New York Times* in 1889. Finding corruption, avarice, and environmental degradation throughout the Adirondacks, an enterprising *Times* reporter told how the lumber barons were destroying the forests:

> They say in this country that the only thing which can elude a lumberman is a moose, which, considering the last of these noble animals was killed not far from where I am writing some twenty-five years ago, is a flattering testimonial to the ubiquitous tree cutter.

The reporter's solution proposed that the state buy up the privately owned forests and consolidate a contiguous public domain. New York governor David B. Hill agreed and in 1890 told the Forest Commission to draw a line on a map of the Adirondacks indicating "the wilder portion of this region covering the mountains and lakes, at and around the headwaters of the several rivers that rise in that locality, including the Hudson." After the state bought all the private land, everything inside this line, declared an overly optimistic Hill, would be the Adirondack Park. The Forest Commission did what the governor requested and on a map submitted to the legislature drew a blue line around the area it wanted included in its proposed park. Although the legislature took another two years to pass the law creating the park, its boundary has always been called the Blue Line.

When Roswell Flower, Hill's successor, inscribed his name on this bill and created the Adirondack Park, both the governor and the legislature expected that the state

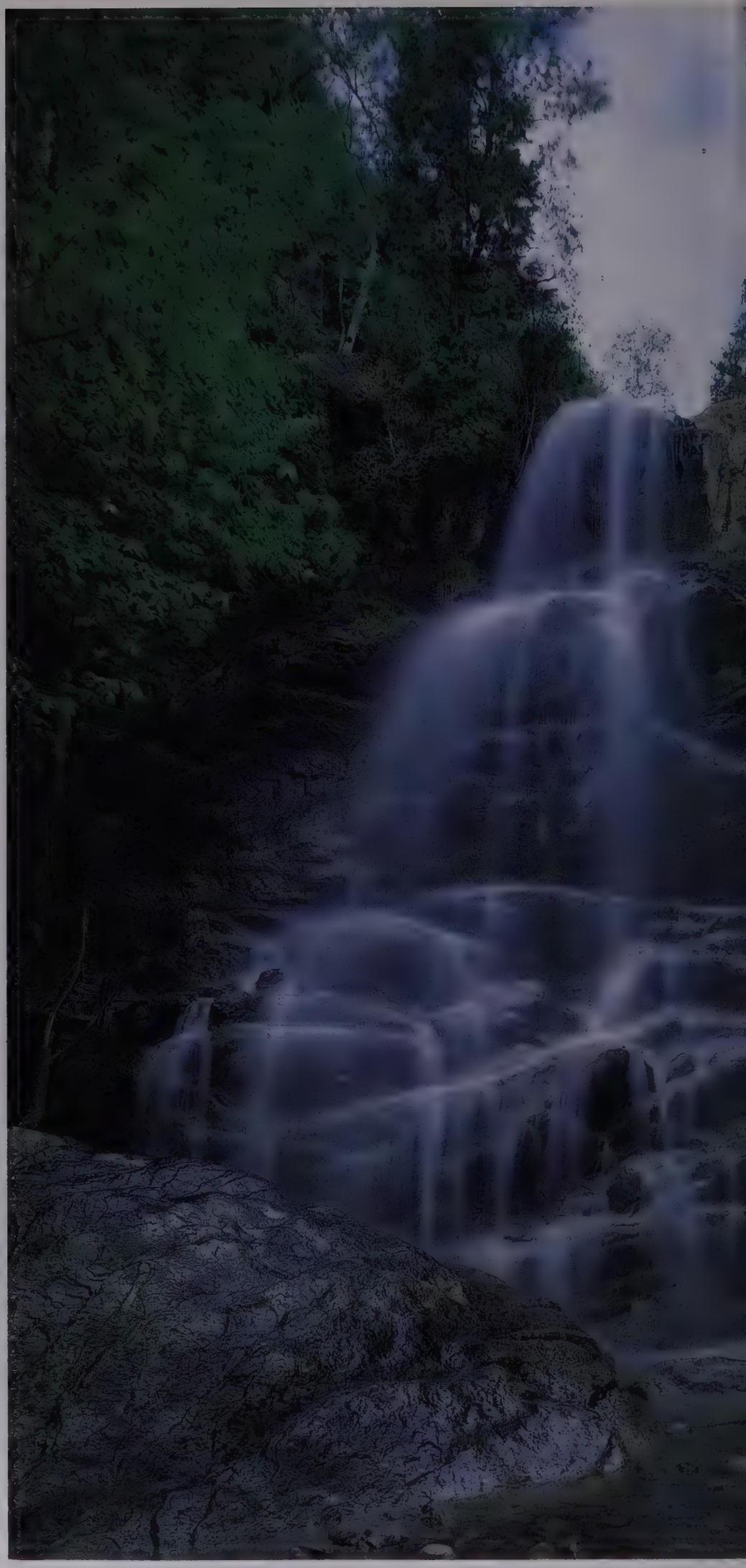
would eventually own all of the 2,807,760 acres then inside the Blue Line, even though at the time the state owned only 551,093 acres, or just under 20 percent of the total. But the park law, like the Forest Preserve law before it, lacked teeth. It delineated an area that the state had an interest in and wanted to protect, but it made no provision for confirming that interest or effecting protection. The newly established park had millions of acres of private land owned by families, clubs, and corporations, and it had thousands of people living in it. It was a complicated checkerboard of public and private ownership, subject to two well-meaning but ineffective laws.

The loopholes in the Forest Preserve law were eliminated at a state constitutional convention in 1894. Worried about just the sort of chicanery and greed uncovered by the *Times* reporter in 1889 and doubting both the competence and honesty of the Forest Commission, the delegates unanimously approved a remarkable conservation article for a new constitution. Building on the current statute, this provision proclaimed:

> The lands of the State, now owned or hereafter acquired, constituting the forest preserve, as now fixed by law, shall be forever kept as wild forest lands. They shall not be leased, sold, or exchanged, nor shall the timber thereon be sold, removed or destroyed.

Precisely the same language has been written into every subsequent state constitution, affording the New York State Forest Preserve just about the tightest protection granted any land in the world.

But the Adirondack region was—and is—far more than just the public domain. With the adoption of the new constitution, New York had a Forest Preserve that was securely protected but too small, and it had an Adirondack Park that was more dream than reality; the constitution did nothing for the private land surrounding the various parcels of the Forest Preserve. As the park begins its second century, pressures to develop private land show that conservation is needed on a regional, not a patchwork, basis. While the framers of the park law recognized this goal, they failed to achieve it. Now the hopes of Verplank Colvin and David Hill reside in a new generation of environmentalists, who are still grappling with the problem of saving the invaluable lands inside the Blue Line. □



Beaver Meadow Falls, in the township of Keene, is part of a tributary that flows into the Ausable River.
Nathan Farb

Still Rising After All These Years

by Yngvar W. Isachsen

Long before politicians created the Adirondack Park by encircling the region with the Blue Line, geological forces had formed the boundaries that define it. Not part of the Appalachians, which lie just to the east in Vermont and stretch from Newfoundland to Georgia, the Adirondacks have a distinct appearance that suggests a different geological origin. Their rough texture, highlighted by myriad rivers and lakes, looks nothing like the long, sinuous ridges and valleys of the Appalachians.

Viewed on a continental scale, however, the Adirondacks are merely a bump on the ancient Canadian Shield. This vast conglomeration of deformed igneous and metamorphic rocks, worn almost flat by erosion long ago, lies exposed from Labrador to the Northwest Territories. The Canadian Shield is the core of the North American continent, a stable platform welded together by repeated continental collisions during Precambrian times. In the United States, these rocks are largely obscured, buried beneath layers of younger sedimentary rocks. The Adirondacks are one of the few places where these Precambrian "basement" rocks poke up through the veneer of Paleozoic limestones, sandstones, and shales. The mountains are carved from a mix of complexly folded metamorphic granites, gneisses, marbles, and quartzites. The minerals of the rocks, formed only at high temperatures and pressures, attest to the rocks' burial deep beneath a terrain resembling the present-day Tibetan plateau.

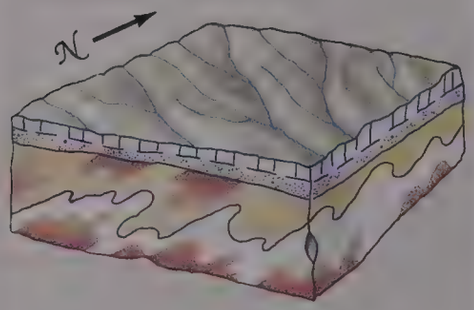
The age of these rocks was easily determined to be about 1.1 billion years by measuring the amount of radioactive decay that has occurred within certain minerals. Figuring out when the rocks were uplifted—the true age of the Adirondack Mountains—is more difficult. One clue comes from the pattern of rivers draining the region. As the Adirondacks began to rise, the flat layers of sedimentary rock covering them were gradually arched upward into a broad dome. From the highest point, the rivers flowed down the sides in all directions, forming a pattern resembling the spokes of a wheel. Erosion easily removed the blanket of sedimentary rock, and then the rivers began to cut into the complexly folded and faulted Precambrian basement rocks, across resistant and weak rock formations. A river's abrasive power acts slowly on hard rocks, such as granite and gneiss. On softer marble, however, gravel and sand moving along the stream bed cut steadily downward, while the water, loaded with acids from decaying vegetation, slowly dissolves the calcium carbonate that makes up the marble. (Today, as they continue to dissolve, these marble belts neutralize the effects of acid rain in most Adirondack lakes at lower elevations.)

If the Adirondacks had been uplifted some fifty million years ago, the original radial drainage pattern would have evolved into one that closely mimicked the pattern of the weaker rock formations. But this has not happened. In the central Adirondacks, rivers and, more recently, glaciers have eroded the weakened rock along ancient faults, forming a number of prominent northeast-trending valleys (such as those occupied by Long and Indian lakes), but most of the park's major streams maintain a radial pattern, cutting indiscriminately across weak and strong rocks, often at right angles. Furthermore, the northern and southeastern margins of the Adirondacks, which dip toward the bordering farmlands, are smooth, tilted surfaces largely untouched by erosion; the Precambrian rock surfaces look as if they have only recently emerged from their cover of sedimentary rocks.

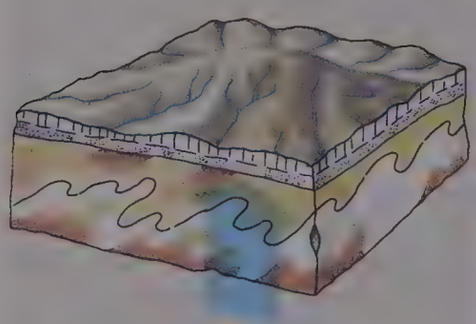
With a rough idea of how fast erosion works, I estimate that 10 to 15 million years were needed to uncover the Precambrian rocks of the Adirondack uplift and wear them down a bit. These mountains are young, especially when compared with the Appalachians, which are more than 350 million years old.

Considering their youth, I have long wondered if the Adirondacks might still be rising. In 1974, Sandford Holdahl, a scientist then with the Vertical Network Branch of the National Oceanographic and Atmospheric Administration, told me

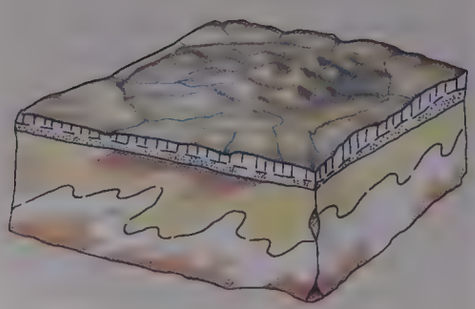
Stages in the Formation of the Adirondack Mountains



Twenty million years ago, before the Adirondacks began to rise, upstate New York was relatively flat. The upper geological layers of the region were deposited at the bottom of shallow seas during the Paleozoic, from 540 to 300 million years ago. Beneath these sedimentary rocks were contorted metamorphic rocks, the roots of a very high plateau that rose up some 1.1 billion years ago and then succumbed to erosion. These are the "basement" rocks of the eastern United States.



Some 10 to 15 million years ago, the earth's crust was uplifted—probably by a rising plume of hot mantle rock—forming the Adirondack dome. A radial drainage pattern formed, and erosion began to remove the veneer of sedimentary rocks.



Today, the dome has been breached, leaving eroded, slightly tilted sedimentary rocks around the margins of the Adirondacks, which are themselves carved from the exposed basement rocks at the center of the uplift.

Joe LeMonnier

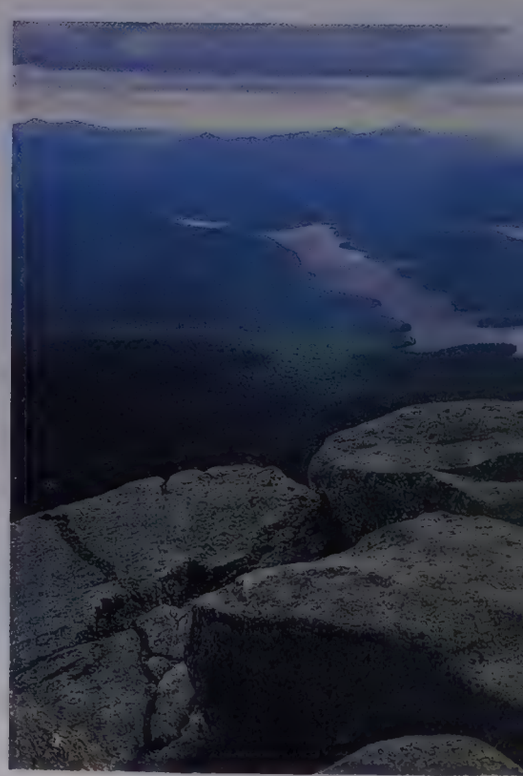
that the survey lines his organization has laid out across the country might provide evidence of the Adirondacks' continuing rise. At regular intervals along the survey routes, brass plates are cemented into the bedrock; the locations and precise elevations of these bench marks are recorded. He mentioned that the lines are occasionally resurveyed, and that elevations of bench marks sometimes change between surveys. On inquiry, I learned that one survey line, along the eastern flank of the Adirondack Mountains between Saratoga Springs and the Canadian border, had been made in 1955 and again in 1973. When I compared the two lines, I found that a slight uplift of one millimeter a year had occurred. The greatest uplift corresponded to the position of the High Peaks, just to the west of the survey line. In 1975, Holdahl and I initiated the releveling of another line that was made in 1931 across the central part of the uplift along the abandoned trans-Adirondack railroad between Utica and Fort Covington. The results showed an upward arching similar to that along the eastern flank of the Adirondacks. Because an uplift of one millimeter a year could raise the terrain half a mile in a million years, I believe that the present high rate represents only a spurt in the much slower growth of the mountains.

In 1987, Carol Treadwell, a graduate student at the State University of New York at Binghamton, examined the sediments of river terraces for evidence of recent Adirondack doming. Originally deposited by floodwaters from melting glaciers, these sediments were exposed where rivers cut through them. Treadwell compared the old terraces above the East Branch of the Ausable River with the profile of the modern stream bed and found that the terraces had tilted since their formation, so that they are now higher toward the central Adirondacks. This confirms that at least some of the doming has taken place since the glaciers receded some 12,000 years ago.

If the Adirondacks are indeed rising, what is pushing them up and maintaining their height against the onslaught of erosion? Most of the earth's youngest mountains are being forced up at plate boundaries. Along these margins, pieces of the earth's crust collide, thrusting up such mountains as the Himalayas and the Andes. Elsewhere, plates pull apart, creating midoceanic ridges, or grind past one another, throwing up mountains like the San Gabriels in California. The Adirondacks, however, lie in the center of the North American plate, almost 2,000 miles from the nearest plate boundary. Such uplifts within stable continental interiors are among the few major features of our planet that cannot be readily explained by the theory of plate tectonics.

In size and shape the Adirondack uplift is unique among the elevated areas of North America, but similar uplifts occurring elsewhere in the world may offer clues to its origins. Some of these, such as the Tibesti Mountains in northern Chad, have signs of recent volcanic activity, indicating that the crust is being heated to higher temperatures than the surrounding region. This heat causes the rock to expand, thereby producing the uplifts. These localized "hot spots" result from plumes of abnormally hot mantle rock that rise up from the earth's interior and heat the crust (the most familiar example is the hot spot that has produced the Hawaiian Islands in the center of the Pacific plate). On the other hand, uplifts such as the Gory Putorana Mountains in Siberia lack evidence of volcanism or even hot springs. But the absence of such indicators above a young plume is not surprising because rock is a poor conductor of heat.

Bore holes drilled more than 1,200 feet into the Adirondack uplifts show no unusually high heat flow. Like some of the other uplifts, the Adirondacks could have risen fairly recently as the mantle and deep crust were warmed by a rising plume; but the heat from such a plume may take another 20 million years to reach the surface. Two geophysical studies conducted by researchers at Cornell University offer indirect support for this view.



Lake Placid as seen from the summit of Whiteface Mountain

Carr Clifton

Anthony Nekut and colleagues measured a hundredfold increase in electrical conductivity beneath the Adirondacks at a depth of twelve to fifteen miles. Such an increase in conductivity could be produced by partly melted rock within the deeply buried gneisses—melt caused by the heat of a rising plume. Another group, led by Larry Brown, conducted a seismic survey across the Adirondacks. Using specially equipped trucks that thump the earth, they sent sound waves into the crust and picked up their reflections from layers deep below. The survey detected numerous reflectors at the same twelve to fifteen mile depth, which also could have been caused by partly melted rock.

The Adirondacks show no signs of high heat at the surface, but the highly carbonated springs along their southeastern border may be the result of an uplift over a hot spot. Carbon dioxide charged springs, such as those near Saratoga Springs and Ballston Spa, lie atop faults that run north along the eastern edge of the Adirondacks. Away from plate boundaries, such springs are rare and are restricted to the borders of large blocks of crust, where deep faults provide the necessary plumbing for carbon dioxide to rise up from the mantle or from a deep source of magma in the crust. The Island Spouter in Saratoga Springs State Park blows ten feet into the air like a geyser. Driven by carbon dioxide pressure, it erupts like an improperly opened bottle of champagne. Although lacking the drama of an active volcano, the spring marks a deep tear in the earth where ancient rocks of the Canadian Shield continue to rise above the lowlands as the young Adirondacks. □

Gore Mountain's Garnets

by William M. Kelly

Courtesy of the Adirondack Museum, Blue Mountain Lake, New York

Gore Mountain, in the central Adirondacks, is best known for its ski slopes, but on its north side is an open pit that has made the peak world famous for garnets. This was the Barton mine, above, which yielded more of the burgundy-colored mineral than any other in the world. Garnet is common throughout the Adirondacks, whose rocks were once baked at high temperatures and subjected to crushing pressures miles below the surface. For some reason the garnet crystals in Gore Mountain grew to the size of cabbages; some reached three feet in diameter. The process may have taken millions of years, as minerals in the surrounding rock dissolved and their atoms recrystallized as metamorphic garnet. Water, which facilitates this transformation as it percolates through rock, may have played a key role in producing the giant crystals; a fault that borders the Gore deposit may have served as a conduit, bathing the rock with water. Or perhaps the special conditions that initiate crystal growth spawned a limited number of garnets; all the available material then gravitated to these crystals, which grew to enormous size.

In the 1850s, Henry Hudson Barton, a jeweler's apprentice in Boston, learned that the garnets displayed in his employer's store came from a large source of the mineral located in the Adirondack Mountains. Years later, in Philadelphia, he married the daughter of the nation's first sandpaper manufacturer. Knowing the great hardness of garnets, Barton reasoned they might make a better abrasive than the quartz or flint in the sandpaper then available. Exploring in the Adirondacks, he located the garnet source at Gore Mountain and produced the first garnet-coated sandpaper. Tested in several woodworking shops near Philadelphia, it proved to be a superior product, and Barton was soon selling all he could make.

Barton began mining at Gore Mountain in 1878; nine years later he bought the entire mountain from New York State. Miners extracted the large crystals with hammers and chisels, storing the ore on the mountain until winter, when the garnet was sledded down to the railroad at North Creek and shipped to the Barton plant in Philadelphia. In 1983, the Barton Mine Corporation closed its operation at Gore Mountain because of concerns over the stability of a 200-foot-high mine wall. The mine was relocated to Ruby Mountain, about four miles north, where it operates today, selling between 10,000 and 12,000 tons of garnet abrasives annually, more than 90 percent of the world market.

The large crystals from Gore Mountain are crisscrossed with natural fractures, so that there is little unflawed material for cutting gemstones larger than a few carats in size. When crushed, however, Gore Mountain garnet breaks with chisellike edges, making it a better abrasive than other garnets. As garnet paper is used, the tiny grains continue to break with angular edges, continually sharpening the paper. Garnet has a variety of other industrial uses, for example, in etching and grinding glass. And the mineral is added to paint to make nonskid surfaces, such as the orange strips that keep people from slipping on New York subway platforms.

William M. Kelly is an associate scientist at the New York State Museum's Geological Survey and curator of the museum's mineral collection.

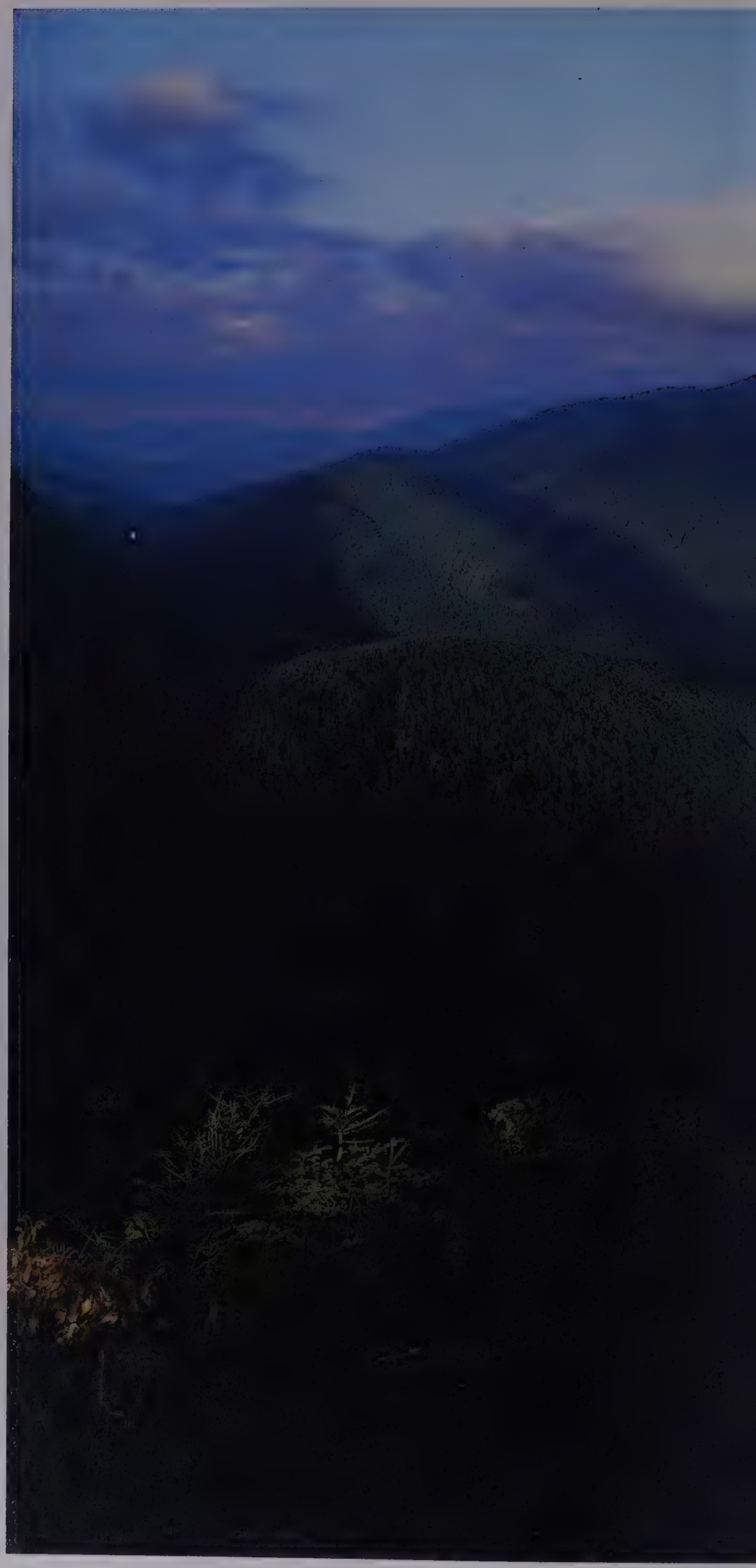
Born-again Forest

by Edwin H. Ketchledge

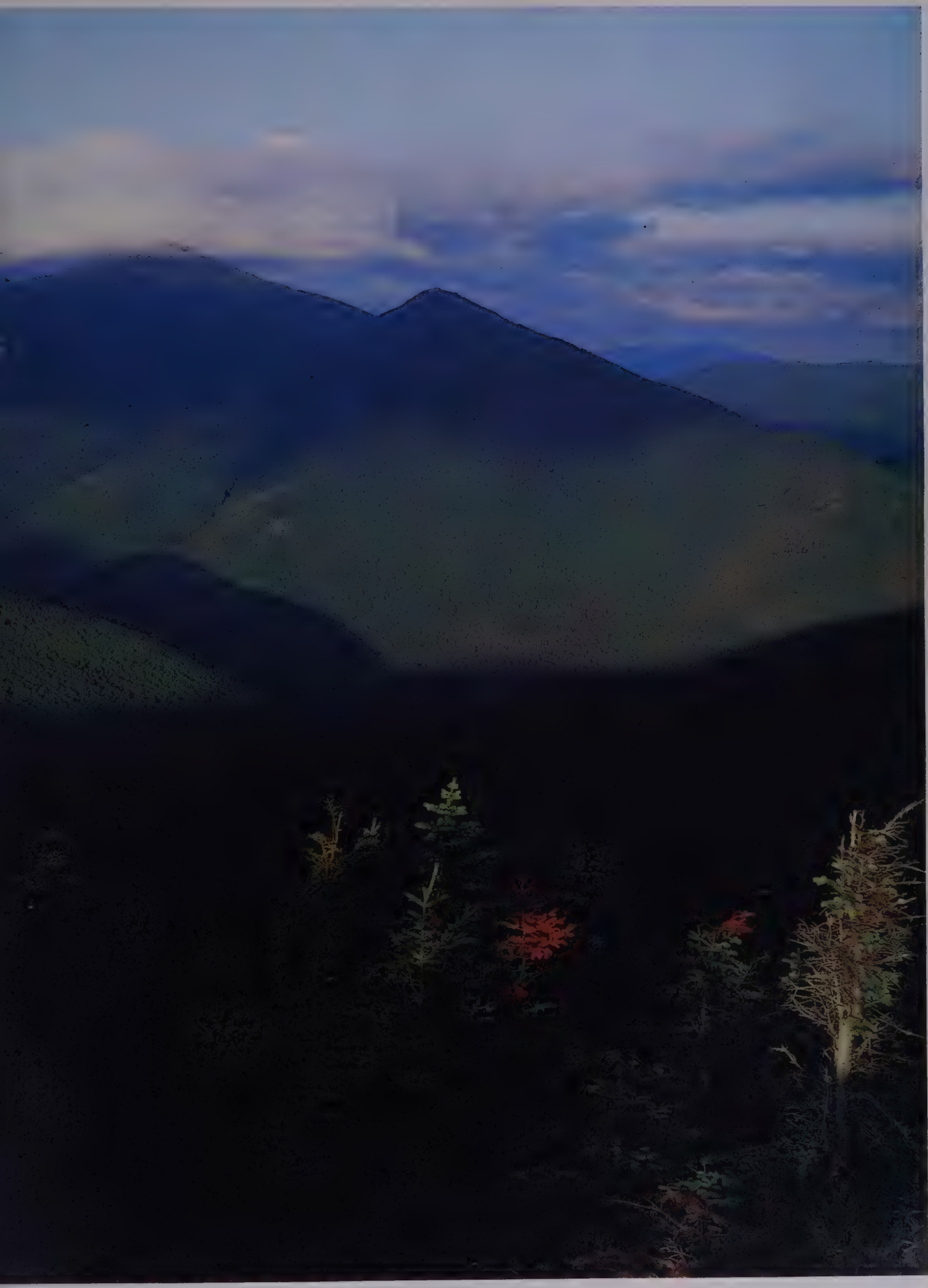
The pulse of a forest beats in years, not in days. Change comes slowly and surely, but shifts in any forested landscape must be measured in decades, centuries, and millennia. The primeval forests that greeted the early explorers in the Adirondacks were themselves new arrivals, the older forests having been destroyed during the Pleistocene Ice Age when continental glaciers swept the landscape clean of all vegetation. Less than 12,000 years on the scene, the fifty or so species of trees encountered by the pioneers had not yet fully settled into balance with the regional climate and soils.

To the colonists, the Adirondack region was nothing but a "dismal wilderness"—a vast, impenetrable barrier of trees, extending unbroken as far as the eye could see and to be avoided during the westward expansion. For miles and miles, four long-lived species—sugar maple, American beech, red spruce, and eastern hemlock—dominated the rich soils of the rolling uplands characteristic of most of the area. Yellow birch was universally present too, because it was an aggressive pioneer in the wake of natural disturbances. The branches of the hardwood trees met in a dense canopy eighty or ninety feet above the ground, leaving the shaded understory to the few plants that could survive with a minimum of sunlight.

Darker and gloomier in the eyes of their first beholders were the conifer forests that grew on the poorer, water-washed soils at lower elevations. Here red spruce, eastern hemlock, and balsam fir grew close together in crowded stands. Fast-growing eastern white pines, commonly



Protected from the ravages of logging, trees are reestablishing themselves in their former stands.
Nathan Farb



125 to 160 feet tall, were widely distributed throughout the Adirondacks, their towering spires poking above the forest canopy. Northern white cedar, too, could be found along many a lakeshore and streamside, but these species were neither as abundant nor as continuous in distribution as spruce, hemlock, and the hardwoods.

Logging changed all this, beginning in 1820. First to go were the big pines, three to four feet in diameter, and two or three log lengths clear of limbs. After three decades, the loggers had penetrated into the very heart of the wilderness but had harvested only the white pines for logs and the hemlocks for their tannin-rich bark.

By the 1870s, however, a process to produce pulp for the paper industry had been developed that could use pine, spruce, hemlock, fir, and aspen. In another twenty years, even maple and beech—heavy hardwoods previously left standing because they would not float in the log drives—were taken when railroads pushed into the interior and could haul every tree away. Of today's 6 million acres, only 200,000 acres of virgin forest remain in the Adirondacks (one-fourth of them in the Five Ponds Wilderness Area south of Cranberry Lake).

Loggers clear-cutting softwoods for pulp left great piles of flammable limbs and slash throughout the forest. Sparks from locomotives' stacks and coals from fire boxes frequently ignited the debris as trains traversed the forest interior. Subsequent fires destroyed 464,000 acres of forest cover in the spring of 1903 and another 346,000 acres in the fall of 1908.

Such severe fires set back the process of plant succession. The organic soil was destroyed along with the vegetation. Consequently, pioneer species, such as quaking aspen, paper birch, and fire cherry, had to grow up before the climax species—spruce, fir, maple, beech, and hemlock—began to reestablish themselves as the dominant trees. Because of the loss of soil through erosion, fires on the steeper mountain slopes were especially devastating, greatly delaying the return of forest cover.

Trees were affected not only by logging and fire but by animal life as well. Deer, for example, were not common within the original forest—too little browse grew on the shaded forest floor in climax stands.

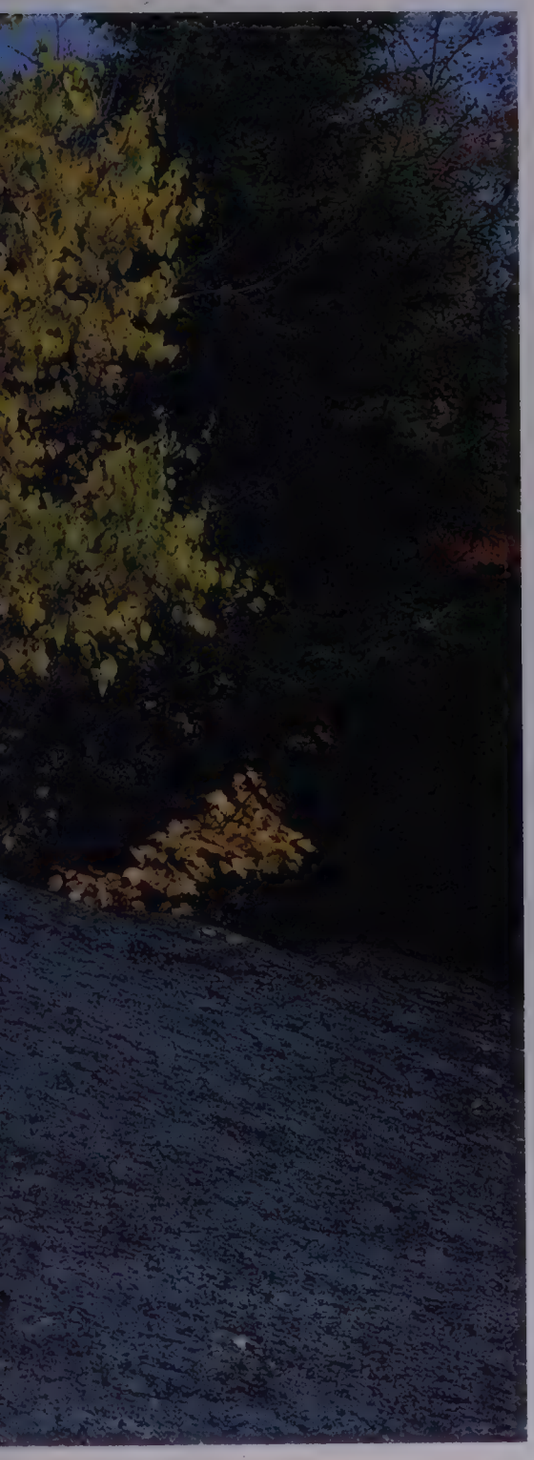
Pioneer species, such as paper birch, grow in clearings where the forest has been disturbed.
James Joern

But the brushy growth that came in after logging, fire, or blowdowns attracted them. By selectively eating maple, birch, and white cedar and avoiding beech and spruce, large populations of deer altered the successional trends—at least until the maple, birch, and white cedar grew beyond the reach of browsing deer.

What comes as a surprise in the Adirondacks is that the forest, so heavily cut over, is now a healthy ecosystem, rebounding vigorously. Most of the modern park had been cut over or disturbed to some extent by the time the Forest Preserve was created 107 years ago. With thousands upon thousands of acres of virgin forest disturbed, the modern forests today are mostly transition forests, different from the primeval stands first encountered. But no important species of forest plant has been lost. On the state-owned Forest Preserve lands, 42 percent of the Adirondack Park, wildness is again returning, at its own slow pace and sometimes in a different but temporary guise compared with its primeval composition.

Standing on one of the higher summits or flying over the mountains in a small airplane, one can see that the major feature of today's Adirondack forests is their conspicuous separation into three elevation zones. The lowlands stand out because of the dark green foliage of the swamp and bog conifers in the peaty, mucky soils, and of the water-tolerant conifers—red and black spruce, balsam fir, and eastern hemlock—that surround every lake and every stream system to the exclusion of pale-foliage hardwood species. On the sandy, water-washed soils bordering the wetlands, where low slopes blend into flat, wet ground, red spruce outcompetes its more demanding hardwood brethren.

For miles around, the rest of the hilly countryside is the pure yellow-green of hardwood species. The heavy conifer logging of yesteryear destroyed the mixed woods (nearly equal numbers of hardwoods and conifers) that once covered these slopes. This landscape, so heavily harvested, now includes sugar maple, American beech, and yellow birch, along with sun-loving hardwood pioneers such as black cherry, white ash, balsam poplar, American elm, eastern hop hornbeam, and other species typically sparse in dense, old-growth forests. Under this new canopy of hardwoods, however, spruce, hemlock, and fir are reappearing, so that in a couple of centuries, conifers and hardwoods will be reestablished in their primeval mix of numbers and sizes. Now the ocean of pale



Trees for Soles

by Barbara McMartin

How did tanbarkers alter Adirondack forests? Between 1850 and 1890, as many as 20 million eastern hemlocks were harvested exclusively for their tannin-rich bark. And since hemlock made up about 15 percent of the trees, tanning had a staggering effect.

Ground up and leached, hemlock bark produced tannin, which could turn animal hides into leather for shoe soles. The hides came from South and Central America and were distributed to about a hundred tanneries in the Adirondack region. About five hemlocks yielded a cord of bark, which could tan four or five hides.

In late spring, tanbarkers cut the hemlocks, scored them into four-foot lengths, pried the bark loose, and stacked it into piles. In winter, teamsters hauled the bark to tanyards, where it was piled into solid, shedlike stacks 8 feet wide, 12 feet high, and up to 600 feet long. A mile of stacks could supply one large tannery for a year.

After the Mohawk and Malone Division of the New York Central Railroad opened up the heart of the Adirondacks in 1892, no new tanneries were built. But the bark was still harvested and shipped out to tanneries elsewhere. By 1926, however, chemicals had replaced bark as the tanning agent for shoe soles.

Of the towns that grew up around the tanneries, many still survive, but a handful, like Jerden Falls, below, are ghost towns. Only its stone foundations, concealed by thick forest, remain to indicate that a tannery town ever existed there.

Barbara McMartin, author of Hides, Hemlocks, and Adirondack History, *is head of the Committee for the 1992 Adirondack Park Centennial.*

Old Forge Historical Society

Paper birches covering much of Cascade Mountain (background) came in after the 1903 wildfires and will, in time, be replaced by balsam fir (foreground).
Carr Clifton

green is broken only on the bluffs and rocky ridges, where just a few species of conifers can grow in the poor soils.

In the High Peaks region, a third forest zone caps the Adirondack landscape. Red spruce and balsam fir thrive in the northern climate of high elevations; there, alone among the hardwoods, paper birch holds on for dear life. Even these three toughest species drop out on a few of the highest peaks and give way to an open, alpine zone of tundra-type plants—dwarf shrubs, hardy grasses, and tough mosses and lichens that withstand extreme winds and wintery weather. These isolated summit populations contain the highest concentration of rare, threatened, and endangered species in New York State.

What will the forest look like in another hundred years? On the private and commercial lands of the Adirondack Park, where lumbering activities and all sorts of landscape alterations—such as tree farms, hunting camps, recreational resorts, and private homes and estates—go along with economic development, we will see the highest ecological diversity. The many disturbances will permit the growth of hundreds of pioneering species.

Approximately half of the landscape—that in the Forest Preserve—will be approaching the original wilderness. Coniferous stands will be dominated by red spruce and eastern hemlock, but with tall white pines on the steep bluffs and dry moraines and an understory of balsam fir in wetter areas. Black spruce and tamarack will continue to dominate sites with a high water table, while red spruce and balsam fir will prevail on terrain above 3,000 feet. Scattered hardwoods, such as yellow birch, paper birch, and red maple, will still grow among the conifers.

On the hardwood sites, sugar maple, American beech, and yellow birch will share dominance, mixed in with hemlock and spruce. The vast array of pioneering species, which now collectively attest to earlier logging history, will be shaded out by the increasingly dense canopy and will only be found where natural disturbances have created open, sunny spaces. Within two hundred years, only the trained eye of the expert will be able to discern any past disturbances on Forest Preserve lands. By then, for all practical purposes, a "second generation wilderness," as I call it, will have returned, and we will have successfully reclaimed our wildland heritage. □

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Doctors of the Wilderness

by Anne LaBastille

In my twenty-odd years as a New York State licensed guide (#0227), I've been privileged to meet many outdoor "living legends." I've also read about a handful of extraordinary woodsmen who "showed the way" in Adirondack woods and waters long before anyone thought of certifying a guide. To me such guides were, and still are, the ultimate woodcrafters, wilderness experts, and caretakers of these magnificent mountains.

The first professional Adirondack guides were few; they earned their reputations by guiding clients, or "sports," usually well-to-do urbanites, on hunting and fishing expeditions in the wilderness. Today's guides still take their guests hunting and fishing, but they also keep their fingers on the ecological pulse of the park. They may be the first to note changes, then sound an alarm when ecosystems go awry, the environment sickens, or fish and wildlife disappear.

Rodney Ainsworth, above, carried on the tradition of "old-time" wilderness guiding into the twentieth century. Right: A Hunting Party in the Woods./In the Adirondac [sic], N.Y. State, *1856, oil on canvas, Frederic Rondel (1826–1892)*
Anne LaBastille

The old-fashioned guides—some of whom I've known and loved—possessed rare traits. Red Perkins, of Old Forge, who guided at the elite Adirondack League Club for forty-five years, was a man of prodigious strength and endurance. He told me this tale from his youth.

Well, you see, this sport wanted his eighty-seven-pound guideboat delivered from Little Moose Lake to Honnedaga Lake for a fishing trip. But I'd already promised my gal to take her square dancing that same evening. I was between a hard rock and a stout spruce. I wanted the $15.00 for the job, *and* I wanted to dance.

So the brawny six-footer shouldered that boat at dawn and made the nine-mile carry to Bisby Lakes in time for breakfast, then back to Honnedaga by lunchtime. Red returned in time for the dance—thirty-eight miles and nine hours later.

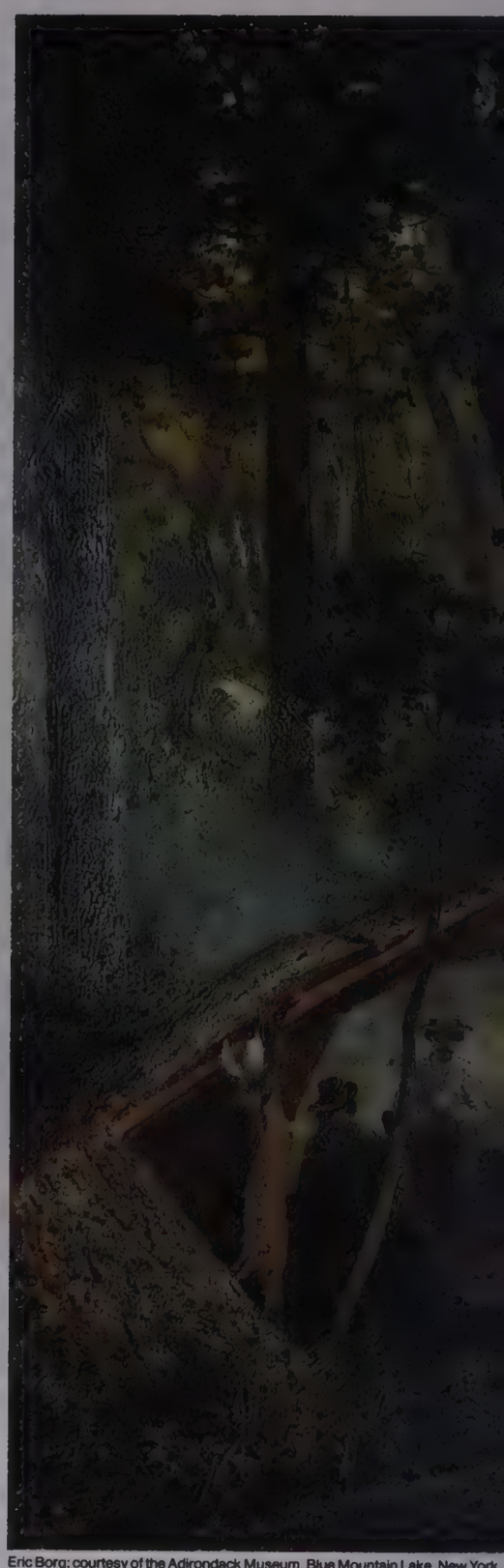
Another guide and friend, Rodney Ainsworth, related how he'd meet the sports at the Big Moose train station and take them to Ainsworth Lodge. Then he'd carry their duffle, guns, food, and fishing tackle into Queer Lake. He came back to the lodge for a guideboat and carried that in, too. He usually reached home after dark, having covered twenty-eight miles on trails. The next day, he showed his carefree clients to the lake for a week of hunting and fishing, trout and venison dinners, and balsam-boughed bivouacs.

Bob Burkhart, a New York City native transplanted to the Adirondacks, was an avid fisherman. He recounted to me his best fishing days.

Took a party to Independence Lake. We followed a stream way, way back until the men refused to go any further because it seemed so small. I told 'em, "Drop these hooks here." We left that afternoon with eighty-seven trout!

Guiding ethics have always required these guides to keep within the legal limits and never personally help fill a client's catch of fish or bag of game.

Three of the mightiest Adirondack guides plied their trade in the 1800s. Alvah Dunning, the hermit guide of Raquette Lake, has been called "the most wily and resourceful hunter, fisher, and trapper ever to live in the Adirondacks." He began guiding with his father in 1828 at age twelve. Often they killed and sold three or four moose in a day. By the winter of 1854–55, Alvah noted the sudden "petering out" of his favorite animal and wondered about it. Yet, he himself claimed in March 1862 to have killed the last moose in the entire Adirondacks. (This claim is contested. Another version states that guide Ransom Palmer of Long Lake shot the last—an 800-pound cow—on the Marion River in 1861.) Throughout his life, the tall, slim, beak-nosed man with the small, keen "snake eyes" lived alone in isolated huts. Dunning guided only those men he liked and considered the best sportsmen.



Eric Borg; courtesy of the Adirondack Museum, Blue Mountain Lake, New York

In distinct contrast, John Cheney, who roamed the wilderness of Essex County for more than forty years, was well loved. He dressed plainly and carried only a jackknife and a long-barreled pistol with a birch-root stock. His unassuming demeanor and unlikely weapons gave little clue to his cool nature and expert marksmanship. During the first thirteen years that John guided, from 1830 to 1843, he took 600 deer, 400 marten, 48 bears, 19 moose, 30 otter, 7 wildcats, 6 wolves, 1 panther, and 1 beaver.

Like Dunning, Cheney never wasted an animal, using its meat, pelt, or hide, and in the case of beaver, its glands. Despite the numbers of animals taken, these men probably had only a minor impact on game populations. More likely, intense logging and subsequent wildfires of the late 1800s caused loss of food and habitat for most wildlife; market hunting also took a great toll.

The last of this triumvirate of nineteenth-century guides was Mitchell Sabattis of Long Lake. He was a full-blooded Abenaki Indian, and late in life was probably the only Abenaki living in the Adirondacks. Shy, small, and resourceful, Mitchell guided for J. T. Headley, author of *Letters from the Backwoods* (1850), and for many ministers of eastern cities. Sabattis's own religious zeal was sparked after he stopped drinking and led to his becoming a leading citizen of Long Lake.

Sabattis and Ransom Palmer are credited with "inventing" the Adirondack guideboat. Guides needed something faster and sturdier than a birchbark canoe: a craft to transport heavy loads, to portage easily, to use as a "tent" on shore, to carry them across lakes swiftly and safely, to hound deer with (dogs chased deer into the water, where they were dispatched by hunters in boats). The first guideboats must have been in use in 1842, for Dr. John E. Todd, a minister, wrote: "We procured a little boat, such a one as a

man can carry on his head thru the woods, from river to river, and from lake to lake."

These sixty-five-pound, sixteen- to eighteen-foot-long boats are still used by guides, as are the traditional Adirondack packbaskets. Probably more miles have been covered in the fast, slim, double-prowed craft, and more pounds have been carried in the light, strong, ash-strip packs, than in any other forms of gear in the Adirondacks. They were the "workhorses of the woods."

In this description of old-time guides, I've not mentioned a single woman. Were there any female guides then? Early records are scanty. Not until 1919 did the Conservation Commission of New York State (now the Department of Environmental Conservation) require guides to register. It was not compulsory, but for those "competent to engage in the business of guiding," a license, badge, and official standing certainly must have been a compelling factor. That year, 176 guides registered and many more applied. A few years later, Julia Ann Burton probably became the first licensed female guide. Born in a log cabin, she learned woods lore and shooting skills as a teen-ager from her French-Canadian-Indian father, then went on to spend fifty years hunting, trapping, and guiding in the Piseco Lake-Jessup River area. None of her male clients ever objected to having a woman "show them the woods." A photo taken in 1941 shows a short, plump woman with a quaint little hat and baggy trousers. Burton was one of very few early guides—many of whom were almost illiterate—who wrote of her experiences. In the 1960s, she said:

> Saw a beautiful doe in the red coat yesterday, and that wonderful color showed so vividly against the green fir trees. Sure was a picture. I can say truthfully, I've enjoyed the beautiful picture but also the tasty juicy steaks—so beautiful on the hoof or on the platter. Feast your eyes upon the picture, fill your empty belly with the beautiful meat. Both very satisfying.

Today, more women guide, but they still come nowhere near the numbers of men. In New York State, a total of 1,098 persons are licensed as guides; 121 are women. Some fifty of them guide in the Adirondack Park.

One of them is me. I obtained my guide's license in the early 1970s and found it a fairly easy process. Bob Burkhart showed me dozens of local trails and lakes over two summers and then vouched to the Department of Environmental Conservation that I "knew the woods." Like most guides, I concentrated on one or two topographic quadrangles around my home. No human being could ever become familiar with the entire 6-million-acre park, or even the 2.6 million acres of Forest Preserve within it. After Bob filled out a simple form, the local game warden had to sign it, verifying that I really could start a campfire, set up a tent, read a map, and cook a meal outdoors. That was it—plus a $2.00 fee.

Today's guides have branched out, and in addition to the traditional hunting, fishing, and camping, many now offer rock and ice climbing, rappelling, white-water rafting, winter skiing, canoeing and kayaking, and backpacking. Still others offer slow-and-easy nature trips and never hold a rifle or rod in their hands. The licensing of a guide has become a serious matter, involving courses and certification in water safety, first aid, and CPR. A statewide examination is given by the Department of Environmental Conservation. Those who pass pay a hefty fee for licensing in the categories of their expertise. But we do it willingly; wearing the oval metal green-and-gold badge is an honor.

Back on June 27, 1891, a large group of guides from all over the Adirondacks met in Saranac Lake to discuss protection of the natural resources, a standard wage, and ethical conduct. Thus, a hundred years ago, a code was established and a private organization, the Adirondack Guides' Association, was formed. It continues under the name of N.Y.S. Outdoor Guides' Association. Members subscribe to a rigorous code of ethics, including a pledge to adhere to "a professional standard of wilderness travel and low-impact environmental use," and to acquire "a useful knowledge of local natural history and the ability and willingness to impart this knowledge to clients." In addition to having had expanded training, most guides own gear never imagined a hundred years ago: aluminum canoes, Kevlar kayaks, inner-frame backpacks, nylon ropes, outboard engines, and Vibram-soled boots. Adirondack guideboats and packbaskets, however, are still used. Most guides carry large insurance policies to cover themselves against lawsuits for negligence.

How is the Adirondack environment they survey different from the wilderness of the old days? Most importantly, populations of many fish and wildlife species are much lower, and certain species have been extirpated entirely. Verplanck Colvin, the Albany surveyor who mapped the Adirondack Mountains for twenty-eight years, gives us a good sense of the fauna then. He climbed trailless peaks and trod through a "howling wilderness" where no white man had ever set foot. In his personal diaries and topographic reports he often noted the abundance of game. In an 1876 lecture, "Winter Fauna on Mount Marcy," he described meeting a "painter" (panther, or cougar)—"an Ishmaelite among beasts." He marveled at the "immensely muscular" cat and found "large massive foot prints" all around the mountain. He also spoke of the "peeshoo," or Canadian lynx, the "black cat" (fisher), the "sable" (marten), a bald eagle, and ravens.

Near Long Pond and Round Lake he reported "signs of bear abundant" in 1873, and at Partlow Lake, he saw a pack of wolves. Near there, a group of hunters shot "sixty to seventy deer in a short stay" to provide Colvin and his survey crew with much-needed meat and took the rest out by boat to sell at market.

This rich diversity of wildlife soon collapsed. Colvin himself is said to have killed the last Adirondack panther in 1877. The "Father of the Adirondack Park" must have divined the changes to come. On Moose Mountain he wrote:

> There lurked deer or bear; perhaps ptarmigan and panther also in the wild desolate forest, living as they had lived since the dawn of creation; but now the march of

civilization had reached even the flank of this great mountain, the lumber roads and skid ways crossed and extended over the trails of the wild game; yet, the dark mountain, in its massive strength, seemed to be as careless as it was motionless, regardless of the [environmental] changes impending.

The changes that Colvin sensed have been enormous. In 1901, the hounding of deer with dogs and guideboats was permanently abolished because of the decline in the deer population brought about by market hunters. And in 1919, a law allowing the shooting of one doe per hunter was passed in an effort to reduce the large numbers killed illegally. It didn't work. Deer continued to decline until the present Department of Environmental Conservation took control; since the 1950s it has passed a series of strict state game and fish laws. Today, wildlife of the state is regulated by the department on a scientific basis and is protected by environmental conservation officers.

The Adirondack Wildlife Program at the State University of New York College of Environmental Science and Forestry, Syracuse, plans to help restore the former diversity of wildlife by reintroducing Canadian lynx, moose, and perhaps wolves and panthers if feasibility studies show that both animals and humans will be safe.

Living in my log cabin over the past twenty-odd years, I have witnessed many more changes. On the dark side is the steady increase in development and population. One hundred and thirty thousand people live full time in the park, and about 10 million tourists visit each year. An explosion of second homes crowd some shorelines. Highway strip growth—small shopping malls, fast-food establishments, and local businesses—has appeared in Lake George, Lake Placid, Saranac Lake, Tupper Lake, and Old Forge.

In the past fifteen years, the native brook trout in the lake on which I live, and in another 300 to 400 Adirondack lakes, have largely disappeared. Red spruce are dying off. Acid rain has had, and continues to have, devastating effects. The gradual deterioration that I witnessed in the backcountry as I guided helped me testify at legislative hearings about this menace and alert the public through writing.

Carrying on the tradition of "doctors of the wilderness," in the words of Ralph Waldo Emerson, guides can be the first to sound the alarm when rabies breaks out, deer, snowshoe rabbits, or beavers decline, or diseases appear in trees, fish, or game.

On the brighter side are the protected areas of open space, silence, and beauty treasured by most guides. Sixteen tracts, or 1.1 million acres, designated true wilderness—the largest such expanse in the eastern United States—now grace our park. No motorized vehicles and no permanent buildings are allowed. Visitors leave only footprints on the trails. More than 1,200 miles of rivers have been designated "wild," "scenic," or "recreational." Off limits to any damming, bridging, or riverbank development, they belong to anyone who wishes to fish, raft, canoe, or kayak. These areas offer peace, enjoyment, and ecological integrity. I can't think of another place in the East I'd rather live or guide in. □

The Sabattis brothers, three other guides, and four "sports" display their deer, in a 1914 painting by Fred Burns.

Anne LaBastille; courtesy of Mr. and Mrs. John Hossley

The Adirondack Guide, *watercolor, Winslow Homer (1836–1910)*

Bequest of Mrs. Alma H. Wadleigh; courtesy of the Museum of Fine Arts, Boston

High-Fidelity Deer

by William F. Porter

In the 1960s, white-tailed deer were at the center of a controversy in the Adirondacks. Browsers, deer live throughout the Adirondacks and spend the summer months feeding on tree seedlings and other plants in the forest; they are especially fond of sugar maple, yellow birch, and other commercially valuable species. Therein lay the "problem": competition between the deer, whose browsing inhibited regrowth of trees, and humans, whose livelihoods depended on harvesting and regrowing the timber.

At that time, there was little debate over what needed to be done—get rid of the deer. There was also agreement over how many deer had to be killed to allow maple and birch seedlings to grow: a 50 percent reduction in the population was hypothesized. Given the ruggedness of much of the terrain, however, disagreement arose over how to achieve that goal.

A young biologist at the Adirondack Ecological Center proposed a seemingly straightforward solution: to hunt intensively on a relatively small test area of 5,000 acres. His aim was to reduce the area's estimated 300 deer to 150.

Other biologists immediately questioned the idea. They maintained, reasonably, that much as gas molecules migrate from an area of dense concentration to a lower one, deer from the surrounding area would move in to fill any territorial vacuums. If the goal were tree regeneration on 5,000 acres, then deer would have to be removed from a much larger area to compensate for this "diffusion" effect. Since some of these biologists were betting men, the experiment became the subject of a wager, with the stakes set at a case of beer.

The experiment was begun in the fall of 1967, and over the next four years, the population in the study site was reduced by the designated 50 percent. To the chagrin of the skeptics, deer from the surrounding areas did not behave like gas molecules. The wager lost and the beer dutifully handed over, the next question was, Why didn't the deer fill the vacuum?

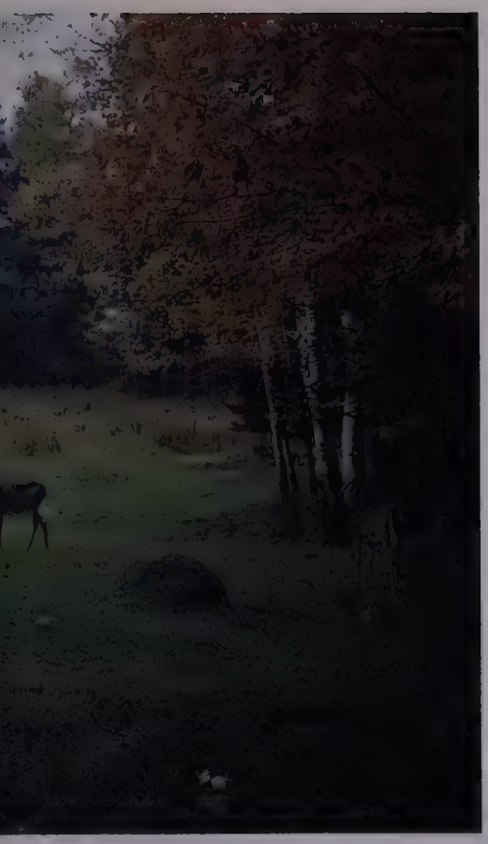
Answering this has led to unexpected findings about the social structure of white-tailed deer in the Adirondacks. During the seventies, biologists at the Adirondack Ecological Center radio collared more than 100 deer. Because each transmitter operated on a different frequency, biologists could identify individual animals. For four years, the movements of collared deer were monitored once every three or four days, providing a picture of the deer's movements over several winters and summers.

The telemetry observations revealed that the deer were absolutely faithful to their seasonal ranges, using the same wintering and summering areas year after year. For the deer, winter "officially" begins as soon as fifteen inches of snow have accumulated (usually by about the first of January). At that time, the deer move down to river valleys and lowlands. There, coniferous trees, such as red spruce, balsam fir, and white cedar, provide food, shelter from the wind, and an overhead blanket that reduces radiant heat loss from the deer's bodies. Deer concentrate in these areas, and the many trails they create allow them to move more easily through the deep snow and to escape from coyotes and bobcats, their chief predators.

Most years, the deer begin to move out of the "deer yards" about the first of April, migrating up to fifteen miles to get to their summer range, where they stay for the next eight to nine months. The deer's fidelity to their summer range provided the clue to the success of the population-reduction experiment: deer outside the removal area were simply too strongly attached to their own range to be drawn to the vacancies nearby. Reproduction by survivors would eventually bring the population in the experimental area back to its previous level, but computer models predicted that would take about five years, just about the time it takes tree seedlings to grow out of the deer's reach.

Such findings were undoubtedly satisfying to management-minded biologists, but scientists with a less practical interest also found them intriguing. How do deer select their summer ranges in the first place? And how do young deer learn where to spend the winter? To answer these questions and others about the social behavior of deer, I began a new round of radiotelemetry studies in 1985. My colleagues and I radio collared adult females, and as soon as they gave birth, generally about the end of May, we radio collared their fawns as well. We also drew blood from every deer captured and used it to examine their genetic relationships.

For several decades, biologists have conjectured that among herbivores, social behavior is strongly influenced by habitat. In open environments, for example, bison, caribou, and musk ox form large groups to



White-tailed deer on the manicured lawn of a private park
Nathan Farb

protect their young from predators. In forests, a female and her offspring stand a better chance of avoiding predators by hiding. Deer living in forests, therefore, might be expected to be largely solitary and to display little social organization.

The findings of the Adirondack studies departed considerably from this expectation. The deer had fairly large summer ranges—an average of about 500 acres per deer—but the ranges overlapped a great deal, at least among the females. Genetic analyses suggest that each summer range is shared by a group of related individuals, probably the daughters, granddaughters, and great-granddaughters of a single female. The deer do not move as a herd in the forest, but we suspect that individuals within a family group are in contact with one another almost daily. Future fieldwork will show just how often the deer interact. There is, however, no question that all members of a group migrate back to the same wintering area, with young deer learning the route from their mothers.

The emerging picture is that of a matriarchy, organized in what we think of as a rose petal pattern. As they mature, the vast majority (more than 95 percent) of young females establish summer ranges that partly overlap with their mothers', like petals on a rose. As more and more generations of females are added to the family group, the summer range expands, at least for a while. Once the group includes about nine or ten individuals, the range stops expanding; additional females are simply packed into the same area.

Between the family groups are areas completely devoid of deer. We don't know yet whether the presence or absence of deer in such areas reflects active avoidance of certain habitats or whether the distribution is simply a historical reflection of where the few breakaway females happened to start their own family groups.

Males follow a very different path. Telemetry records show that more than 80 percent leave their natal area between eighteen and thirty months of age. They appear to move until they find another group of females and then establish summer ranges near one or two such groups. When the time comes, they tag along with one of these groups to a winter range.

The durability of this social structure depends on how long the females live, which in the Adirondacks is frequently past ten years. In the 1980s, we captured two females that lived to be fourteen and sixteen years old, respectively, before being killed by coyotes. Such longevity in the wild is unusual, for over most of the white-tailed deer's range, hunting pressure is heavy, and females seldom live more than three or four years. On farmland, for example, up to 40 percent of the females are killed every year. In the Adirondacks, the inaccessibility of much of the land, and a current ban on the harvest of antlerless deer (females and young males), allow the deer to live longer.

The size of social groups depends on the severity of Adirondack winters. In theory, deer populations can grow rapidly. Adult females breed every year, generally conceiving for the first time at eighteen months of age. In their prime years—from age three to eight—females tend to bear twins. Under ideal conditions, a population could quickly double.

Life in the Adirondacks, however, is far from ideal. Winters are cold. Snow often reaches a depth of three feet; more importantly, it lasts a long time. For fawns born the previous spring, winter often lasts too long. Our data show that when winter (defined as the number of days when snow on the ground exceeded fifteen inches) lasts more than eighty days, most fawns die, succumbing not so much to the snow or cold as to the lack of food. Fawns spend most of their first summer growing, with little energy left over for fat reserves. Since the Adirondack winters are usually a little longer than eighty days, the inescapable conclusion is that a large proportion of fawns must die every winter.

A few rough winters in a row are unlikely to cause any immediately noticeable decline in the population. Adults, unlike fawns, do build up fat reserves over the summer and can last a full 120 days on the winter range. But in time, if no young females are being added to the population, it will grow smaller. When winters are mild (about a third of the time), many more fawns survive. How one mild winter affects the population depends not so much on the very next winter as on the one after that, when the fawns will have reached breeding age. Then, if the winter is mild again and if there are a healthy number of adult females producing twins, the population can increase dramatically.

We were somewhat surprised to learn that predators have less influence on deer populations than has sometimes been proposed. Black bears and coyotes kill about 30 percent of the fawns each year, generally within the first four weeks after birth. But once fawns have survived their first month of life, their chances of surviving to adulthood jump to 80 or 90 percent. Barring a severe first winter, that is. If enough rough winters kill off enough fawns, then every additional fawn or breeding female lost to predators will drive the population down and prolong its recovery time.

An estimated 75,000 white-tailed deer now live in the Adirondacks. My colleagues and I plan to continue our studies, and we hope that in the years to come we may also have an opportunity to study the largest member of the deer family, the moose, in the north woods of New York State. Moose disappeared from the Adirondacks in the middle of the last century, done in by unregulated hunting. In the past twenty years, however, populations of moose in Maine, New Hampshire, Vermont, and Quebec have grown dramatically, and some moose have made their way into the Adirondacks. Unfortunately, most of the twenty to thirty now living here are young bulls, the individuals most likely to wander away from home.

There have been several proposals to restore moose to the Adirondacks by live trapping them from Canadian populations. None of these proposals has been implemented, in part out of concern that brainworm (a parasite common in deer and thought by some researchers to be lethal to moose) would kill any moose brought to the Adirondacks. Recent research has cast doubt on the seriousness of the brainworm threat, however, and we now believe moose can survive. A study is currently under way in Ontario's Algonquin Park, and we are optimistic that one day soon we will be seeing cow moose from Ontario nursing their calves in Adirondack meadows. □

A Taste for Venison

by Rainer H. Brocke

On the southwestern horizon, the glow of sunset touched the top of Wolf Mountain with soft pinks and reds, highlighted by the first snow of early November. Contemplating the silent scene beyond the fire of my modest hunting camp—a lean-to, sleeping bag, backpack, and little else—I was at peace with the world, a peace I sought annually in my fall pilgrimage to this central Adirondack wilderness.

Suddenly, the silence was shattered by howls, yips, and yodels, seemingly a mere few yards away. I had heard coyote howls before, but this was a full-dress concert of unearthly exuberance. Mixed with the deeper howls of adults were the high-pitched yips and yaps of their progeny. Punctuating the serenade was the deep wailing howl of a coyote that reminded me of nothing other than a wolf. While most coyote group howls rarely exceed two minutes, this one seemed to last an eternity.

As suddenly as it had begun, the concert was over, but the peace of this night was not to be restored for long. The coyote group, or pack, as I prefer to call it, howled repeatedly throughout the night, always from the same location. At dawn, I jerked awake to their finale. Apart from lost sleep, I was delighted at this turn of events, for I had made field contact with no ordinary coyote pack. This particular pack was being tracked telemetrically by Gary Brundige, a graduate student of mine and a Ph.D. candidate at the State University of New York College of Environmental Science and Forestry, Syracuse. Brundige and I had been studying coyote ecology at Huntington Forest, a 15,000-acre research station near Newcomb in the central Adirondacks. Recently, these coyotes had shifted their activities northward to the remote state wilderness area where I was camped.

Judging by the consistent direction of their concert, I was certain the pack had something substantial to howl about. Had they "camped" by a deer carcass, feeding on it throughout the night? After a quick breakfast, I headed in the direction of the night's serenade, looking for coyote tracks and evidence of predation in the snow.

I soon realized that the coyotes had been farther from camp than I thought—a good 250 yards away. They were long gone by the time I arrived, but under a dense stand of balsams, I found all that remained of their kill—a few deer vertebrae, a chunk of hide, and scattered hair.

Harsh mountain winters may have forced the eastern coyote to adapt its diet.
Esther Schmidt; Valan Photos

Surrounding this was a sea of coyote tracks, but no other meat, bones, or body parts. By following tracks in the snow, Brundige had learned that a pack of coyotes soon dismembers its kill, each animal feeding on a chunk it has removed and then stashing the uneaten portion in some hiding place away from the kill site, usually in a pile of leaves or duff or in a snowbank. Presumably, the coyotes later uncover these edibles and consume them in tougher times.

No matter how many such kill scenes I see, I am always impressed because—although I know better—I have been thoroughly programmed to believe that the coyote is the smallish "song dog" of legend, inhabitant of the western prairies, a predator of mice, ground squirrels, and jack rabbits, when not pursuing cartoon roadrunners over the horizon. As I surveyed the kill site that crisp November morning, I might as well have chanced upon the work of the coyote's larger relative, the one that dominated these lands just 150 years ago, the one that inspired the name of the nearby pinnacle—Wolf Mountain. But the coyote can and does kill deer, especially on the northern fringes of its range in northeastern, midwestern, and northwestern North America. The coyote's propensity to prey on deer in the Adirondack region confirms its great adaptability—in this case, to harsh winters, deep snow, and a shortage of smaller prey in winter.

To identify the seasonal composition of the coyote's diet, Brundige collected and analyzed 1,007 scats (fecal droppings). Scats were washed and broken apart to separate hair, bone chips, and animal parts. A look through the microscope at the various hairs helped Brundige identify what mammals the coyotes were eating: the white belly hairs of a deer, for example, can be readily differentiated from the white hair of a snowshoe hare's winter fur. The tiny skulls and bones of shrews and mice are also diagnostic, as are insect parts and berry seeds.

Some foods are more digestible than others; worms and some fruits, for example, are often nearly completely digested, leaving little evidence of their passage in scats. Therefore, we can never be positive that we have a complete record of all the foods a wild animal has been eating. Careful analysis can, however, permit a reasonably accurate picture of an animal's diet, including an idea of the relative proportions of the various foods in it. Brundige's calculations led him to estimate that white-tailed deer make up in excess of 80 percent of the coyote's diet in winter, and a significant, although lower, percentage in spring and summer.

In the fall (September through November), deer consumption drops dramatically. During this season, when a large variety of food is available, the coyote feeds on beavers, snowshoe hares, muskrats, porcupines, red squirrels, chipmunks, and other small mammals, as well as insects, birds, blackberries, apples, and beechnuts. In short, if an item is edible and available at ground level, the coyote will eat it.

But fall smorgasbord aside, the white-tailed deer is the principal food for coyotes throughout most of the year in the central Adirondacks today. Has it always been so? To find out, Brundige designed his scat-collection routes to coincide with those of two earlier studies, one by William Hamilton of Cornell University, conducted from 1956 to 1961, and another by Robert Chambers of our college, conducted from 1975 to 1980. A comparision of Brundige's results with those of the previous studies indicated a definite trend over the years: since the 1950s, coyotes in the Adirondacks have been eating more and more deer. The study demonstrated that winter consumption of deer rose from about 40 percent of the diet in the fifties to nearly 90 percent in the seventies and more than 90 percent in the last decade. Summer consumption also went up significantly. During the same period, the percentage of small prey in the diet declined, in both winter and summer.

Significantly, coyote consumption of deer went up independent of deer density. The 1950s—when coyotes ate relatively few deer—saw the highest deer population densities ever recorded in the area: about twenty-five deer per square mile. Deer numbers subsequently declined to about five per square mile in the 1970s, following severe winters; yet, at the same time, coyotes increased their consumption of deer to approximately the present high levels. By the mid-1980s, deer numbers were back up again, to about twenty per square mile.

What then accounts for this trend in the coyote's eating habits? Part of the explanation may lie in changing coyote demographics. At the turn of the century, the eastern coyote was rare in the Adirondacks if it was there at all. (There is currently some dispute among scientists on this point.) The presence of the gray wolf throughout the East in the 1600s and 1700s precluded significant coyote populations (gray wolves tend to displace coyotes from their home ranges). By the late 1800s, however, the wolf had been extirpated by settlers. This predator vacuum, coupled with the buck law (which made it illegal to hunt doe deer), contributed to an explosion of deer throughout the East during the first half of the twentieth century. Coyotes apparently spread into New York and the Adirondack region from northern Michigan and Minnesota and through Ontario, Canada. This population front appears to have reached the Adirondacks in the 1930s, spreading to points east in the 1950s and 1960s.

Up until the seventies, coyotes were sparsely distributed in the Adirondacks, and we hypothesize that they probably hunted alone or in pairs. If true, this may explain the low proportion of deer in the diet during this period, for bringing down a deer alone is hard work, even for the big eastern coyote. (At an average weight of twenty-eight pounds, and with weights of up to forty pounds for males not being uncommon, the eastern coyotes measured in our study overlap the low end of gray wolves in Ontario, which weigh from forty to eighty pounds. One of the road-killed coyotes we found weighed in at fifty-five pounds.)

Currently, we calculate central Adirondack coyote densities at about one animal per every nine square miles. In his study, Brundige counted track sets in snow and dirt throughout the year and estimated that in summer (when coyotes feed on more small prey), more than three-quarters were of solitary animals, while in winter (when deer make up the bulk of the diet), about 70 percent represented pairs or packs.

In the central Adirondacks, we found that coyote pack life revolves around a dominant male and female, the breeding pair. Young of the year remain with their parents; hunting with them in winter, they help raise a new litter the next spring. The packs, which resemble those of wolves, operate essentially as a territorial family unit. Over the course of the last thirty years, the coyotes in these packs may have developed a tradition of pack hunting, a sort of deer-hunting culture.

Much is known about this intelligent, adaptable predator. The Plains Indians had a special respect for its intelligence. In their many myths and legends, it was Coyote who performed the cleverest tricks, who was given special cunning by the Great Spirit, who danced with the stars, who was sent to earth to kill the monsters and other evil beings among the ancients, and who taught the Indians how to do things. Judging from our experience, Coyote still has much to tell the world. □

Beaver Waterworks

by Dietland Müller-Schwarze

In 1609 the French explorer and founder of Quebec, Samuel de Champlain, estimated the beaver population in the area then known to Native Americans as Couchsachraga, and now called the Adirondacks, at one million. Although his estimate was undoubtedly much too high, the area was rich in these large rodents. This abundance was reflected in the language of both Indians and European settlers. Couchsachraga has been variously translated as "beaver hunting ground" or "at the place of the beaver dams" (or, according to another version, "dismal wilderness"). Maps of the region are peppered with countless Beaver lakes and ponds, Beaver creeks, Beaver meadows.

Native Americans used to trap beavers for fur, moccasins, and meat, but that had little effect on beaver populations. Shortly after the Europeans discovered this valuable furbearer, however, fur wars broke out in the Adirondacks between the Algonquins and French in the north and the Iroquois, Dutch, and British in the south.

By 1623, the animal was so important to the economy of New Netherland (the Dutch colony along the Hudson River) that it appeared on that colony's seal. For the next two hundred years, the beaver was trapped relentlessly. Its fine hair was worked into felt for expensive beaver hats. In the late 1600s, beaver pelts, or "brown backs," served as currency in New York. In the 1790s, the steel trap became common, making trapping even more efficient and deadly. Excessive trapping was followed by habitat loss, a result of both settlement and logging. By 1820, fewer than a thousand beavers survived in northern New York. Fortunately for these few hangers-on, the fur of a South American rodent, the nutria, entered the market at this time as a substitute for beaver fur in the making of felt. And soon, silk replaced felt as the material of choice for hats. By 1870 beaver hats were out of fashion.

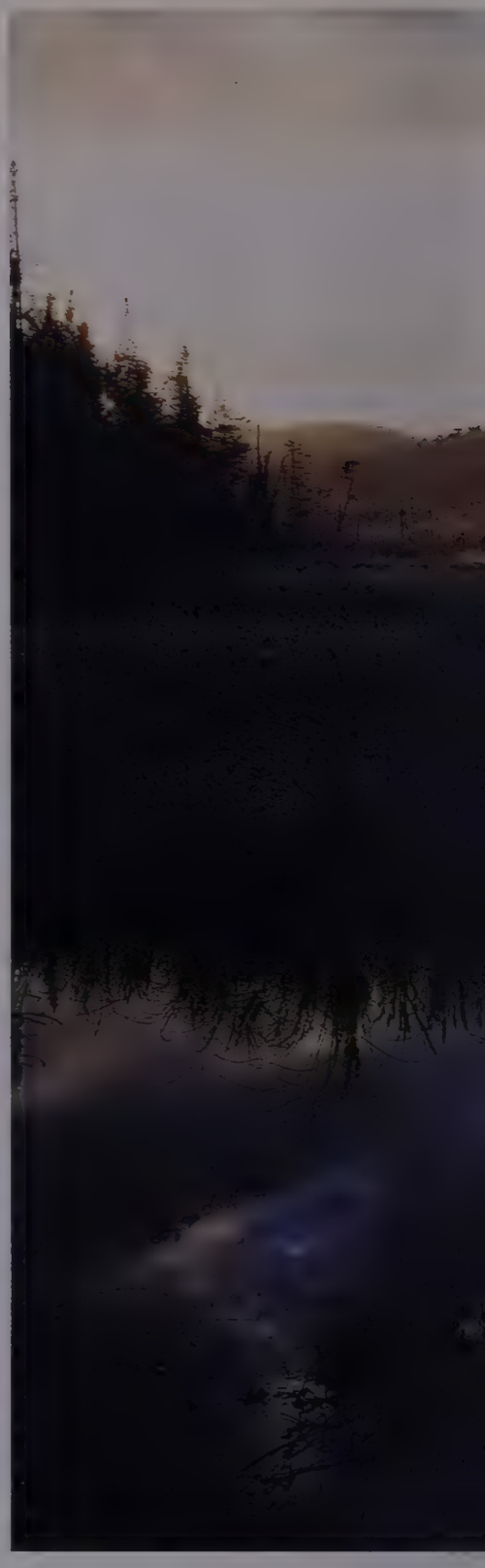
But relief came almost too late. Beaver numbers continued to drop until, according to one 1895 estimate, only five to ten animals remained in all of northern New York. That year, in an eleventh-hour attempt to ward off impending extinction, the state passed laws decreeing that "there shall be no open season for beaver." In 1904, all trapping, molesting, or disturbing of beavers or their dams and lodges became illegal. In another move to restore the species, the state of New York bought seven beavers from the Canadian exhibit at the Louisiana Purchase Exhibition in Saint Louis and released them near Old Forge in 1905. Two years later, fourteen more animals were brought in, this time from Yellowstone National Park. Altogether, thirty-four beavers were released between 1901 and 1907.

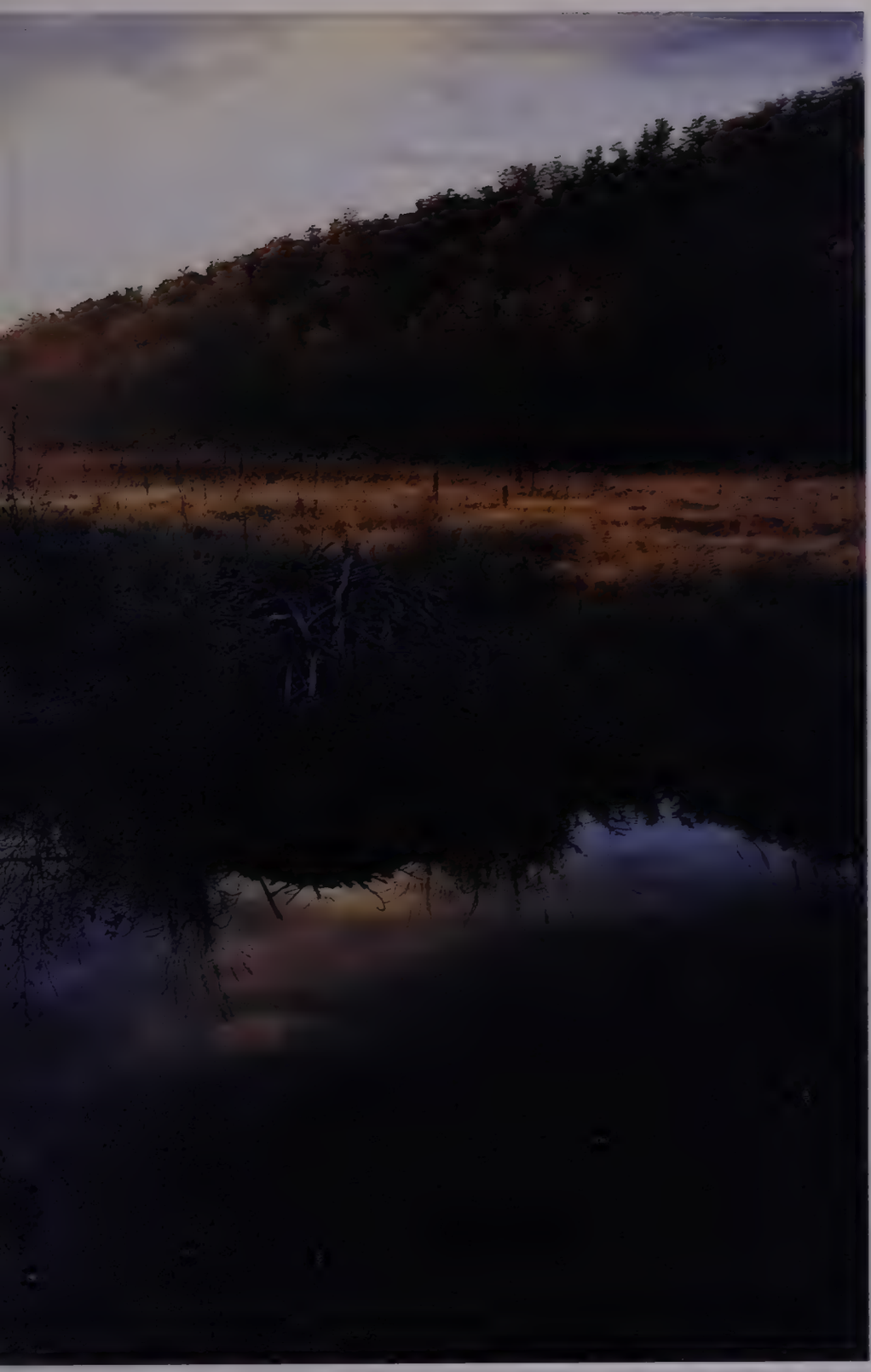
The beavers responded well to the efforts on their behalf. By 1908, their numbers reached 150; by 1915, the population had grown a hundredfold, to 15,000. The beavers owed part of their remarkable resurgence to the destructive forest fires of 1903 and 1909, which cleared the land for the aspen trees that grew in the fires' aftermath and on which beavers thrive.

Today, an estimated 14,000 to 18,000 beavers inhabit the Adirondack Park. They are now so common that monitored trapping is permitted, and hikers in the north woods are well advised to filter all water to avoid contracting giardiasis, also known as beaver fever. This intestinal infection is caused by the protozoan *Giardia lamblia,* which is released in cyst form into the water through beaver feces.

Thanks to the beaver's impressive recovery, biologists and visitors alike can observe just how crucial a role this rodent plays in the Adirondack ecosystem. The region is blessed with an abundance of water, but much of the land is steep and rugged. Without beavers' dams, much of the water would flow unchecked through the heavily forested landscape. By impounding water and felling trees, beavers not only provide themselves with wood for their lodges and twigs for food, they also open up the dense woods, creating opportunities for a variety of plants and animals.

As more and more trees fall, sunlight pours in through the new openings. It warms up the shallow, slowly moving water that now spreads beyond the original stream boundaries to form a pond. Grasses, sedges, raspberries, and wildflowers spring up along the pond margins. Aquatic and land insects thrive, providing a food base for such songbirds as song sparrows, tree swallows, and cedar waxwings. Water birds, such as kingfishers, mergansers, and wood ducks, breed and feed in the larger beaver ponds. Beaver-killed trees provide valuable nesting cavities for many birds, including tree swallows, wood ducks, and mergansers. Toads, frogs, and newts propagate, often profusely, in shallow parts of the ponds, providing food for herons and mammalian carnivores. The water and its surrounding vegetation attract white-tailed deer, raccoons, minks, and otters. Muskrats often move right into the lodge with the beavers, picking up their food scraps. Moose, now returning to New York State, also benefit from the beavers' activities. In addition to





A beaver colony opens up dense woods, creating benefits for many animals.
Nathan Farb

feeding on vegetation both in and around the ponds, moose wade out into the water in search of relief from biting insects.

In their early stages, beaver ponds often permit trout and other fish to grow larger, since they can find more aquatic insects and zooplankton to eat in the large volume of warm water than they can in swift-flowing, cold streams. But if water slows down too much and becomes too warm, trout begin to suffer. Cold-water fish, trout spawn on gravelly stream bottoms; as mud accumulates on the pond floor, they can't spawn at all or their eggs suffocate. But these are seldom problems in the Adirondacks. For one thing, as a study of tagged fish in California showed, the dams present less of an obstacle to trout movement than might be imagined: provided the water level is high enough, the fish are able to cross beaver dams in both directions. For another, the dams break periodically, especially in steep terrain, giving a boost to fish migration and dispersal; the rushing water that follows a dam break also flushes out mud.

Over time, beavers remove all their favorite trees from around the pond. First to go are the aspen, then the hardwoods. Eventually, much less desirable spruce and other evergreens dominate the shoreline. When beavers abandon a pond—perhaps when suitable trees have become too hard to find and transport—the dam deteriorates and a beaver meadow develops on the accumulated silt. Considered choice grazing sites by early settlers, these meadows often determined where settlements would sprout up. In today's tree-covered Adirondack wilderness, open areas are rare, and beaver meadows provide grass for several species, including white-tailed deer, moose, and even bears.

When looking for a place to build a new dam, beavers prefer streams with a gradient of up to one percent: dams are easier to construct there; a larger area can be inundated; and destructive flash floods are less likely. Also, in flat terrain the pressure of the water that builds up in the pond can be distributed over a longer dam.

At their present high population level, however, some beavers are forced to eke out a living in much steeper terrain, even near mountaintops. I found one marginal site near the summit of Mount Marshall, where, at 4,200 feet above sea level, a tiny beaver pond sits, surrounded by nothing but balsam fir, lowest on the beaver's diet list. I encountered another at 4,350 feet as I approached the summit of Tahawas, the Cloud Splitter, which is New York's highest mountain and more commonly known as Mount Marcy. The beaver living there had dammed up the highest creek in all of New York State; its home pond is tiny Lake Tear of the Clouds, the source of the mighty Hudson.

The current abundance of beavers in the Adirondacks has led to some complaints. We hear about "nuisance beavers" that cut down trees and flood valuable property or roadways. Beavers have even been blamed for the acidification of lakes. Their life style does put more dead organic matter into the water, but recent work demonstrates that at least in the larger, slow-moving beaver ponds, bacteria growing on decaying vegetation counteract any increase in acidity that might result from its decomposition.

By and large, however, beaver detractors are few and far between. The return of the beaver, the official mammal of New York State and keystone species of the Adirondack wetlands, is generally a source of pleasure and satisfaction to young and old. And while not all animals are as prolific or adaptable as the beaver, its recovery inspires me to hope that similar success stories may one day be told about other beleaguered species in the Adirondacks and elsewhere. □

Return of a Native

by Peter Nye

Loons wailing eerily in the early dawn haze; a moose foraging in the shallows; a cougar lapping water; a majestic bald eagle perched silently on a stout pine limb overhanging the water—this may have been a typical scene at any one of many Adirondack lakes in the early 1800s. Better make that the early 1700s, just to be safe. By 1960, no nesting bald eagles lived in the Adirondacks, and only one pair were to be found in all of New York State. To understand just what happened to our national bird in the Adirondacks, we need to take a look back at the region over the last two centuries.

In his book *The Adirondack Park: A Political History,* Frank Graham, Jr., provides some enlightening glimpses into what was going on in "the great northern wilderness" during this time. Trees along the rim of this mountain region began to be cut as early as 1763. The first of many lumber mills in the area was built that year in Glens Falls. Major rivers served as conduits for floating logs from interior sections to the mills. In 1806, the New York legislature declared parts of certain rivers, such as the Raquette, Schroon, and Salmon, "public highways," not only for boats but also for the transportation of logs, no matter who owned the shores. Graham indicates that by this early date, Glens Falls was on the verge of collapse, as all the nearby forest had disappeared. The town essentially got a new lease on life as interior, upstate areas were lumbered and logs were floated downriver to its mills.

By 1845, 7,000 sawmills were operating in New York. By 1849, lumbermen were cutting trees near Blue Mountain Lake, considered the heart of the wilderness. A staple commodity, wood was used for construction and fuel; it provided charcoal for the iron and steel industry, potash for manufacturing, and bark for the thousand tanneries in the state. Later, logs became a valuable source of pulp for paper making and wood for railroad ties. Incredibly, logging hit its zenith in the upper Hudson River watershed by 1872 and declined thereafter. Even with the advent of the crosscut saw in 1891 and the growth of railroads during the late 1800s, the volume of logging never matched what was taken out earlier by the ax.

Hunters, fishermen, tourists, and well-to-do summer campers also flooded into the Adirondacks. "Camps" were being built by city folk as early as 1786. The famous Prospect House, built on Blue Mountain Lake in 1832, boasted 300 guest rooms. Hotels and guesthouses, many of them opulent, sprang up throughout the Adirondacks, and all proclaimed the availability of fresh venison and trout daily, providing some insight into the status of game laws and the mind-set of the day. By 1836, Lake Pleasant, in Hamilton County, had already become a popular resort for hunters and anglers, and rumblings were heard that the fringes of what we now know as the Adirondack Forest Preserve were overused by hunting and fishing parties. Many of the great camps maintained logbooks with columns not just for visitors' names but also for the number of "trout taken." Loons and eagles, perceived as competitors for prized brook and lake trout, were wantonly persecuted. Nearly all the great camps of the Adirondacks had at least one mounted bald eagle, shot locally; in my early years in the mountains I saw many of these trophies.

Despite evidence that suggested the Adirondack region, with its abundant water and fish resources, was once prime habitat for bald eagles, in reviewing the literature of the 1800s I was surprised at the absence of bald eagle reports. In every description of a fishing or hunting party gliding down a remote river or lake in search of a "trout hole" or a deer on the shore, I expected to find a sentence or two describing a huge stick nest a hundred feet up in a shoreline pine. I found no such accounts (although I may have missed some). This is even more startling given the detailed accounts of other wildlife that was still encountered, including rattlesnakes, turtles, moose, bears, loons, trout, and deer. Mention was occasionally made of a perched eagle, but none of nests or nest trees. From all of this, one can only conclude that bald eagles were already rare in the Adirondacks after 1850.

Bald eagles are the only representative of the family of sea eagles living in continental North America. Primarily fish eaters, they are closely associated with rivers, lakes, and oceans. Early visitors to the Adirondacks found a panoply of beautiful rivers and lakes replete with fish. Accounts abound of the sheer wealth of many species of game fish, particularly lake trout and brook trout. By 1870, however, the fish resources of the Adirondacks were dwindling; many of the most noted areas were said to be fished out.

The northern white pine, the favored bald eagle nest tree in the northeast, was also once abundant. According to the *Roosevelt Bulletin* of 1920: "In the original forest, white pine towered aloft as the most important element of the Adirondack mixed woods." White pines are often supercanopy trees: they provide both a commanding view and large, horizontal, whorled support branches that make them ideal as bald eagle nest locations. William F. Fox, in his 1901 *History of the Lumber Industry in the State of New York,* described New York in 1600 as nearly completely forested and essentially "a white pine state." Trees towered 125 to 160 feet high and had two- to four-foot diameters.

Given the water, isolation, abundant fish, and white pines, bald eagles must have done quite well in the Adirondacks in the 1600s and 1700s. Perhaps 100 to 200 pairs made their home there. The number of places named after eagles is also silent testimony to their former stature in the region.

The bane of the Adirondack bald eagle was most likely the destruction of its home sites. Softwoods, and particularly white pines and spruces, were in great demand. Beginning in the 1700s, white pines with their tall, straight trunks were prized as ships' masts. Their preference for low-lying, sandy soils that tended to be found immediately around lakes and rivers was another strike against these mighty trees, making them accessible to loggers both for cutting and for floating to mills. By 1890, white pines had become scarce in the Adirondacks.

Despite dramatic historical accounts to the contrary, the Adirondacks were never logged over entirely. However, the preferential removal of white pines, particularly along watercourses, must have had a tremendous effect on bald eagles in the area. The loss of nest sites, combined with the loss of fish and the indiscriminate killing, drove them from the region.

My colleagues and I identified eighty locations in New York believed to have been bald eagle nesting sites between 1880 and 1960. One-third were within the Adirondack region, primarily in Hamilton and Franklin counties. By 1940, only a handful of pairs could be identified; yet

Eaglets about two months old survey their new home near Deer River.
Peter Nye

the oft-mentioned culprit DDT wasn't put into use until the 1950s, when the last few nesting bald eagles were already struggling for their survival here.

Fortunately, efforts begun more than a hundred years ago to create an Adirondack Forest Preserve literally set and nurtured the seeds of what are now 100- to 150-year-old white pines. These were to become the pillars upon which a new population of Adirondack bald eagles would nest. All we needed were the eagles.

In July of 1983, twenty-three nestling bald eagles arrived by small charter jet at Lake Clear Airport in the heart of the Adirondacks. These eaglets, taken some twenty-four hours earlier from productive nests in Alaska, were destined to become upstate "New Yorkers." My colleagues and I were launched on an effort to restore the bald eagle to New York and to the Adirondacks, once the bastion of the bird in our state.

The idea of releasing young bald eagles in the absence of parent birds, a process called hacking, was conceived by noted ornithologist Tom Cade, then of Cornell University. We began with the release of two birds in central New York State in 1976 and expanded over the years to three other locations in the state. The objective was to release enough young eagles at various locations so that at least some would eventually mature and establish themselves as adult breeding birds.

Finding the right release site is the bedrock upon which a hacking project rests. Wildlife biologist Gary Will and I reviewed the potential Adirondack choices. "Too public" and "too much human disturbance" quickly eliminated 75 percent of them. Too little prey or lack of large white pines ruled out others. Although it was private property and access would be a nightmare, I had chosen Follensby Pond before I ever laid eyes on it or had even met the landowners, the McCormicks. A visit to the place only confirmed my initial belief that this was the best bald eagle rearing site in the Adirondacks. It was centrally located; large, isolated, and undisturbed; full of fish and white pines; and the very last occupied bald eagle nesting location known in the region. Fortunately, "Bird" McCormick strongly supported our work.

Before the arrival of the eaglets, we had boated supplies across the 1,000-acre "pond" and built hack towers within sturdy hemlocks on the shore. Roomy hacking cages and a remote-controlled video camera were placed atop the towers. Once the eaglets were installed in their temporary homes, our hacking team monitored them twenty-four hours a day. On August 16, 1983, the first two "new" Adirondack eagles became airborne; the other twenty-one duly fledged and followed. After three years of hacking, forty-nine Alaskan-born bald eagles were plying the powder-blue Adirondack skies.

The science, or perhaps more appropriately the art, of turning nestling eagles into successful, independent young birds that think and behave like eagles is difficult, yet critical. Even if successful, however, it leaves part of the job unfinished. To reach the ultimate goal, these pioneers must survive five years to sexual maturity, find a mate and a nesting place, and procreate as per the grand plan. By 1988, part of our "historic Adirondack wildlife scenario" had been re-created; a majestic white-headed eagle perched silently in search of food near its nest in Franklin County. More nests were to follow in rapid succession, and by the summer of 1991, four nesting pairs had been confirmed and six of their young were banded and fledged that year. Over just four years, fifteen eaglets have fledged and have joined the growing Adirondack population. And other, as yet unknown nests may already be out there. Even today, many "unpeopled" areas may be holding additional natural treasures. Nesting pairs will accrue annually as more hacked eagles breed and more of their young come of age.

To check on the progress of our latest pair of eaglets, I scaled a 100-foot white pine and climbed into the six-foot-diameter nest, joining its young occupants. From this elevated vantage point, I gazed at the white clouds and blue sky above and the convolutions of the blue river below—some of the best homecoming sights the earth has to offer. Welcome back, bald eagle. □

Moonlight Cantata

by Judith W. McIntyre

In *Adventures in the Wilderness* (1869), the Reverend William "Adirondack" Murray described an encounter with a common loon:

> The shrill cry of a loon piercing the air broke my heavy slumber, and brought me to my feet in an instant, rifle in hand.... The sight was good and the lead well sent, but the agile bird, ever on the alert, had gone under with the flash.

Murray and a companion pursued the bird by boat and, after fifty shots, finally succeeded in wounding it. And what had the loon done to provoke the murderous chase? It had disrupted their fishing.

Common loons are indeed fish eaters; a mated pair and their two young will consume about half a ton of fish during a six- to seven-month breeding season. But today, while they are seldom shot by human competitors for tasty game fish, loons face new threats. Acid rain has killed off the bounty of fish, motorboats buzz secluded nesting spots, lead and mercury have infiltrated once pristine waters. In 1979, I compared old records with recent surveys and estimated that 35 percent of New York's natural lakes were no longer home to nesting loons, as they had been forty to seventy years earlier.

In contrast to this bleak picture, one human artifact has proved, indirectly, unexpectedly, and happily, to be a boon for common loons, the species found in the Adirondacks. Rivers have been dammed, and the resulting reservoirs have become prime real estate for these birds. The reservoirs' islands and quiet back bays attract breeding loons, while their size and fish populations make them desirable stopovers for migrating loons. Since 1977, I have studied the loon population of Stillwater Reservoir and have found that it is the largest for a single lake in New York State, with between nine and sixteen pairs nesting yearly.

Each spring, common loons fly from Atlantic, Pacific, and Gulf coastal waters to lakes in Canada and the northern United States. There, pairs establish territories of some 50 to 150 acres, where they nest and raise their young. Just before freeze-up in the fall, they return to the ocean. Some of the loons that winter along the Atlantic coast nest in the Adirondacks. We don't know if and where they pause during migration; perhaps they fly nonstop. With a flight speed of about seventy-five miles per hour, and a good tail wind boosting it to a hundred, just a few hours of flight time could bring these loons to their summer homes.

Pairs begin arriving in the Adirondacks in April and immediately claim territories. Nesting may begin within two weeks, but three or four weeks may pass if water levels are too low or too high to reveal old nest sites, which they often reuse. The choice of territory is all important. The key seems to lie in its appearance. Does it seem to be private? Does, for example, a promontory or a long spit separate two bays on a lake, lending each an air of seclusion? Neither humans nor other pairs of loons are welcome as the birds settle down to their intimate task. A pair will often take over a small lake of fifteen or twenty acres. Some pairs use two or three lakes, keeping ownership over one for nesting and using the others for feeding.

Once a territory is secured and a nest site selected, the pair bring up plant material from the bottom of the lake, throw it shoreward, and take turns sitting on, shuffling, and shifting the wet mound of vegetation until it begins to resemble a nest.

Females lay two eggs, and incubation takes about four weeks. Sometimes the male and female divide sitting duties equally. But in 1991 my students and I kept a vigil during the last sixteen days of incubation for one Adirondack pair, and we found that the male sat each night and did about 60 percent of the incubating. The eggs are covered by one or the other parent at least 95 percent of the time. If both members of the pair must leave the nest to intercept an intruding loon, for example, the eggs are vulnerable. Lacking camouflage coloration, they can readily be seen by predators.

Although loons run across water when fighting or taking off, they cannot walk and are reduced to scrambling awkwardly up inclines to reach the nest. They build nests at the water's edge so they can slide underwater at the least sign of danger. But if the water level drops, the distance between water and nest increases, and they must then struggle overland to get on and off the nest. I have watched a loon spend half an hour clambering to its nest, but the more time and effort involved, the greater the chance that the loon will simply desert the nest.

Nest loss is even more common when water levels rise. Heavy rains, combined with an extensive watershed, cause many nests to flood. I found that nests were lost when waters rose more than eight inches. Loons may attempt to offset the rising water by adding more material to the nest, but eventually, the eggs are washed out.

Because of these precarious conditions, with either too much or too little water leading to nesting disaster, some researchers have introduced floating artificial nesting islands that have been accepted and used by loons in many northern lakes. I first placed artificial islands on Stillwater Reservoir in 1986 and tested their stabil-

A common loon in breeding plumage nests on the shore of a lake in New York State.
Kip Taylor

ity by sitting on one myself. Despite my demonstration, the loons ignored them.

In early June of 1991, I was determined to try them again; heavy spring rains had caused water levels to rise at the beginning of the incubation stage. Because the season was still young, I knew the loons would probably renest if their first attempt met with failure. (In contrast, in 1987, when water levels rose late in June, only one chick was raised on the reservoir.) But I wanted to see what would happen if the loons were given positive encouragement to use platform nests.

With the help of my students and my husband, I towed an artificial island across the lake and positioned it next to a nest that was being inundated with water. The loon pair moved just far enough away to watch yet still feel safe. I picked up an egg that had washed into the water and removed the other from the nest before my companions hefted the soggy, forty-pound nest onto the platform. I placed both eggs back in the nest, one cold and wet, the other still warm.

Would the loons accept this strange structure? After we retreated, the pair approached the nest, looked in, and poked at the vegetation. Then they swam around and under the platform before climbing aboard. We held our breath as one loon flopped onto the nest, raised itself, turned the eggs, and settled down to incubate.

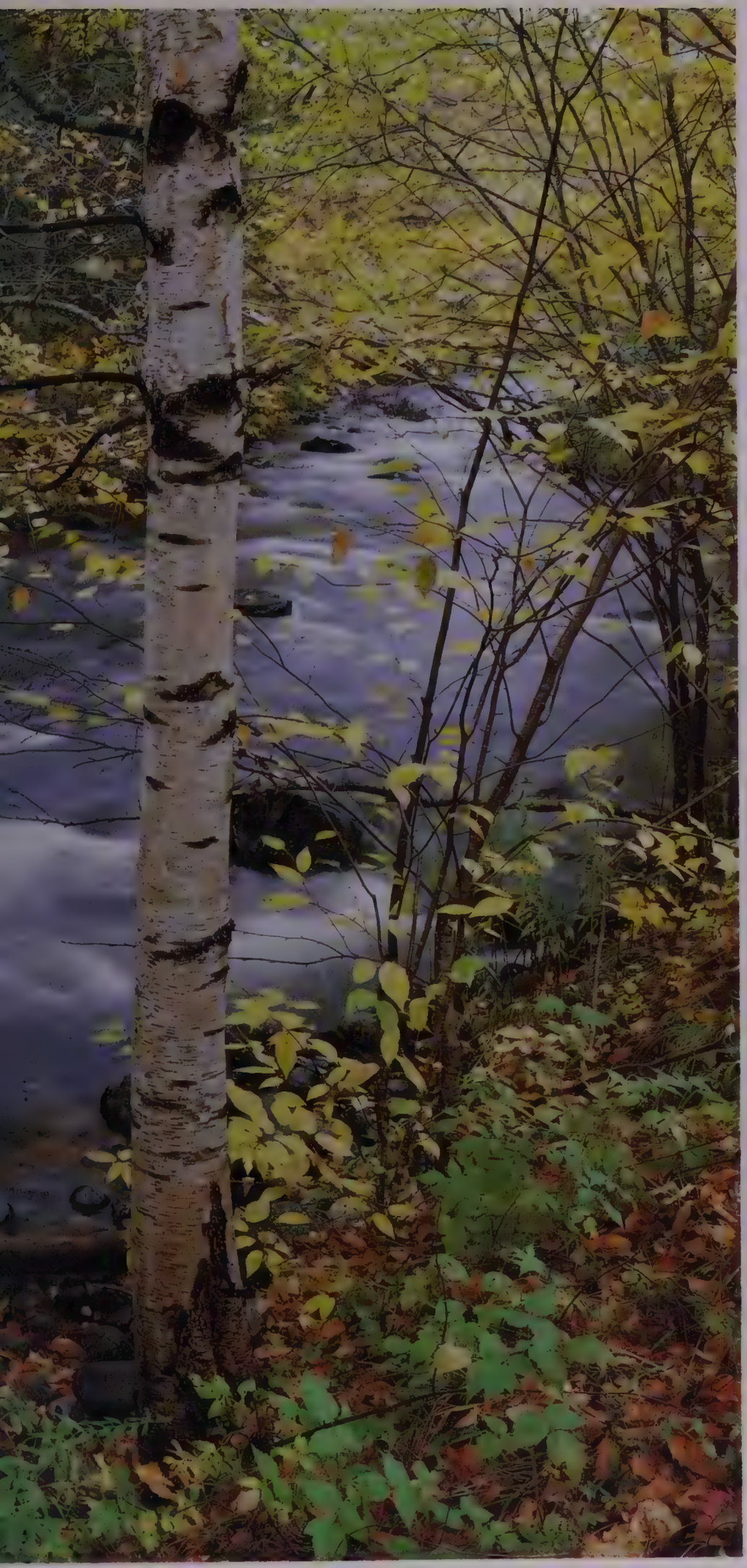
On June 20, two fuzzy young appeared; even the dislodged egg had survived to hatch. Chicks hatch a day apart. The first out of the egg takes short swims but returns to be warmed by a parent until its sibling hatches. When the second hatchling is dry, both take to the water and a fight ensues. This determines which will be the dominant "boss baby," although the older chick inevitably wins the fight and the privilege of always being fed first. If the lake does not support enough small fish to sustain both chicks, at least one will be fed and have a chance to survive.

In the Adirondacks, where acid rain has reduced fish populations, more and more loon pairs are seen with only a single young by August, although two-chick broods were once common. The drop in food supply, combined with mercury and lead poisoning and human activities that disrupt nesting, can seriously hinder common loon reproduction. Yet, the Adirondack population I study is more than holding its own. I believe this is so because of the benefits provided by reservoirs.

By going through old records, I tried to reconstruct my study area, from the time when only a river meandered through it to the present day. In the mid-1800s, the Beaver River was adjoined by a few small lakes, four of which were probably large enough to have supported one loon pair each. Over the years, massive lumbering operations spurred the construction of canals, dams, and impoundments. A dam completed in 1905 raised the water level to 1,660 feet above sea level, many feet higher than the original level. Early maps suggest that the reservoir was large and complex enough to accommodate eight pairs of loons. By 1926, further dam construction resulted in an expanded reservoir nearly twenty feet higher, with 6,300 acres of water and double the number of prospective loon territories.

Since 1977, between 9 and 16 pairs have occupied territories each year, for a fourteen-year total of 168 pairs and 97 fledged young. The original four lakes and river could have produced a maximum of 32 young during this same time. Average productivity is now the same as that on major Canadian lakes in the heart of loon country. Indeed, if you are at the Stillwater on a midsummer's night in 1992, you may think you are in the Canadian wilds. One hundred years ago, loon calls were rarely heard at the Stillwater. Today, they echo nightly across the water and across time.

During the day, the sounds of motorboats, jet skis, and firecrackers can be heard. To preserve loon-filled nights, we must be willing to control the pressure of human-dominated days. Loon music is a gift to wilderness visitors. It deserves a reciprocal gift of protection from us to assure that it rings out for the next one hundred years. □



The Once and Future Wilderness

by Bill McKibben

Pictures are a big problem. When photographers set out to capture the Adirondacks, they are inevitably seduced by the towering rock of the high peaks, by the storms that bring record cold and snow, or by the bears and deer and bobcats and fishers and lynxes. Or by the perfect, glassy lakes or the thousands of streams and roaring wilderness rivers that drain this great range. On film it always ends up looking like Yellowstone East, minus the bison but plus the loon.

And that is deceptive. Not that the Adirondacks aren't a majestic, noble range, every bit as grand and scenic as anything in the West. Beyond that calendar façade, however, is another kind of glory and grandeur: the region's vast significance for environmental questions that affect the entire planet.

In the first place, not all of the Adirondacks is eight-by-ten glossy grand. A lot is "just" low forest, endless hills, thick swamp—all the sorts of places that have been cleared and civilized in the rest of the lower forty-eight. Away from the rocks and ice, the bulk of the roughly 3 million acres of the Forest Preserve will never draw vast numbers of tourists. It's more important to biologists—for once, an entire ecosystem was protected—and to those of us who want a sense of what much of the world used to look like: the great transition forest stretching to the horizon, unbroken by road or clear-cut.

But a second fact about the Adirondacks may be even more salient. Unlike

Birches and understory vegetation fringe a swift mountain brook in the Preserve.
Carr Clifton

Condos and cabins on Lake Placid: wilderness with all the creature comforts
Nancie Battaglia

Yellowstone, this is not a wilderness set apart. This is a wilderness interwoven with human settlement. The park covers 6 million acres (making it larger than Yellowstone, Glacier, and Grand Canyon national parks combined). Of that, about 3 million acres are public land, "forever wild" under the state constitution. The other 3 million, which weave in and out of the state forest, are private land. Some is timberland, some is vacation land, and some houses the small hamlets that contain nearly all the 130,000 residents of the park. There are fairly tight regulations—in some places you need eight acres before you can build; in others, it takes forty. State review and permits are required for any substantial development. But people live there—people coexist with the magnificent wildlands. And that makes it very special indeed.

"It's the example that really casts a beacon for the rest of the world," says Thomas Jorling, the commissioner of the state's Department of Environmental Conservation (DEC). "You can't figure out a way to manage wildlife on the African plains unless you can figure out a way to manage people as well."

Managing people is not an easy task—humans as a species are notoriously independent, and Adirondackers are no exception. The history of the park is largely a history of conflict between those people who thought land use should be more tightly controlled (for many decades, mainly aristocrats who made their money in Manhattan and summered on enormous private preserves in the park) and those who resented state oversight (mainly people who lived here in the winter, too). In recent times, much of that tension has focused on the state-run Adirondack Park Agency, and in particular on a commission formed by Gov. Mario Cuomo in 1990 to make recommendations for the park's future.

That commission, after a year of hearings and deliberation, produced a report as visionary as any environmental document ever written by a government agency. Painting both with broad strokes and in delicate detail, it proposed new regulations on everything from the color of guardrails to the creation of important new wilderness areas: one to preserve the rare tract of boreal forest on the park's northern edge; another to link together the vast Oswegatchie wilderness, nearly half a million acres at the park's core.

But the report's ecological vision was matched by a near-total political blindness. Even before its official release, Adirondackers were screaming about new state schemes to regulate every detail of their lives. And although much of the opposition was manipulated by real estate developers, it was hard to argue it entirely away when the commission report recommended restrictions on what colors people could paint their roofs in an effort to ease the eyestrain on backpackers.

The reaction to the commission's report dominated local politics for at least a year. New groups sprang up—Solidarity Alliances and Fairness Coalitions. It seemed like every pickup in the park had a bumper sticker reading The Adirondacker: An Endangered Species. Hundreds of people brought traffic along the main interstate to a crawl by motorcading to Albany at thirty miles per hour as a protest demonstration. Someone even ambushed a truck belonging to the Adirondack Park Agency, putting several bullets in the occupied cab.

In the year since, the state bureaucrats have been trying to pick up the pieces. How they go about it will go a long way toward determining the vitality of the Adirondack idea. "The governor's genius has been to realize that the commission's report exacerbated hard-line feelings in ways that were unnecessary," says Jorling. "Ever since, we've been looking for common ground," most recently in a series of new proposals by the governor.

And that common ground may not be impossible to find. "Many people in the Adirondacks hold the view that government is patronizing, and that the less government the better," says Jorling. "But the people who hold that view differ little [from environmentalists] with respect to their value systems. Many of those people are just as open to protecting the great open spaces."

One aversion native Adirondackers and "flatlander" environmentalists share is to the condoization of the park, which is destroying the local culture as surely as it is degrading the scenic hillsides. There aren't many roads in the Adirondacks, so all the egregious new developments are quickly visible to everyone, a daily slap in the face—the prefab condos, the signs advertising subdivisions with names like "The Crick," aimed at people who think mountain folk talk funny. A stretch of these monstrosities and you're yearning for a junked car or two, even though the governor's commission called them eyesores and urged their removal from people's yards. "I went to one meeting of an Adirondack rights group that had been opposing any restrictions," said DEC official Robert Bendick, "and the first guy who stood up said there should be no second homes at all in the Adirondacks."

But the temptation to sell out has always been strong for locals too—the Adirondack counties are perennially the poorest in the state, finishing below even Brooklyn and the Bronx. To slow the helter-skelter breakup of family lands, the governor recently proposed a series of conservation easements that would pay residents to keep their land intact. At the moment, the debate centers on whether the law would apply to the smaller parcels many Adirondackers own. If it does, many of them would be happy at the prospect of being paid to maintain their way of life.

"We have to stop going along with the notion that land exists to be whacked up into grids," says Robert Glennon, the executive director of the Adirondack Park Agency.

Some in the Adirondacks may also be starting to see that state regulation comes with benefits as well as costs. In December 1991, for instance, one of the counties that straddles the park line decided to site a new landfill within the park—a 375-acre dump designed primarily for refuse from cities outside the Adirondacks. Although the issue isn't settled, the state has taken solid steps to keep this kind of development at bay. If that happens, says one local official, "we'll be able to say to people, 'Look, state regulation isn't all bad.' "

The slowly spreading reasonableness—still confined to pockets of an as yet inflamed park—has begun to find a political voice in the newly formed Residents Committee to Protect the Adirondacks (RCPA), the first conservation group in the park's hundred-year history not dominated by outsiders (and a group to which I belong). Some of the members of its steering committee are the sixth and seventh generations of Adirondack families—typical Adirondack families, which is to say poor Adirondack families. In a widely read series of publications, they have pointed out that the Adirondack legacy is really two legacies. One is a fiercely independent streak—locals don't want outsiders telling them what to do. The other, and it runs just as deep, is a love for the quiet and beauty of the mountains. Increasingly, Adirondackers are willing to sacrifice some of the first heritage in order to preserve the second—a bargain, but perhaps not a bad one. "The RCPA represents a rational strain that I think ought to be encouraged," says Craig Gilborn, director of the Adirondack Museum in Blue Mountain Lake and a member of the governor's controversial commission. "There's simply going to have to be a recognition that there will be limits on what we can do with our property if we want it to be like this in a hundred years."

DEC commissioner Jorling says he believes the state legislature will mark the park's centennial year with at least some legislation, perhaps adding additional (although not ironclad) protection for shorelines and backcountry land and at the same time approving the tax easement for residents who keep their land intact. In addition, the state continues to work on economic development proposals that could boost tourism and also improve the economics of the local timber industry by putting more furniture making and other "value-added" activities within the park.

One task the financially strapped Empire State will almost certainly *not* take on this year is purchasing additional land within the park. The future of land acquisitions—chunks like the 50,000-acre Whitney estate, or the 87,000 acres that belong to a Georgia land speculator named Henry Lassiter, or a 20,000-acre tract of boreal forest now in the hands of International Paper—was clouded in the fall of 1990. Six months after a million New Yorkers rallied in Central Park for Earth Day, the state's voters nixed a bond

Climate Change in the Adirondacks

by Stephen T. Jackson

The hundreds of lakes studding the Adirondack landscape appear to most people as scenic breaks in the forest cover, tubs full of game fish, or arenas for testing their muscles or motorboats. While I too marvel at their beauty and enjoy eating their fish and stretching my tendons paddling across them, I appreciate Adirondack lakes in another, more peculiar way. I see them as video cameras, permanently embedded in the landscape, passively recording changes in vegetation and environment over thousands of years.

Each spring, flower-dust storms roll through the air, depositing a yellow film of pollen on lake surfaces. Wind gusts and rivulets carry needles and seeds from nearby forests into the lakes. Much of the pollen and plant debris sinks and becomes entombed in the mud on the lake bottoms. As the mud accumulates, each year's crop of pollen and plant litter is preserved.

By plunging a hollow tube into the mud of an Adirondack lake and hauling it up, I can obtain a record of the history of the surrounding forest over the past 10,000 years. Because pollen can travel many miles on the wind, it records the large-scale changes in forest composition, smoothing over the more subtle shifts in local stands of trees. The larger plant fragments, however, provide a record of the trees growing near the lake. By examining the needles and seeds from the mud at six Adirondack lakes, I have been able to reconstruct forest changes at specific altitudes, ranging from 2,100 to 4,300 feet.

Although vegetation patterns may appear to be permanently engraved on the Adirondack landscape (barring human disturbance), the lake-mud records lead to a more dynamic perception of the vegetation. Climate change has resulted in nearly continual changes in regional and local forest composition during the past 10,000 years. As the climate changed, individual tree species shifted up and down the mountain slopes. For instance, between 8,000 and 4,000 years ago, trees now found at lower elevations—white pine, hemlock, yellow birch—grew at altitudes as much as 1,000 feet higher, indicating substantially warmer temperatures during that period. Cooling trends over the past 3,000 years have led to the disappearance of these trees from higher elevations and increases in spruce populations.

During the elevation shifts, forest zones (groups of associated species) were not preserved; distinct zones emerged, persisted for a while, and were then replaced by new patterns. The characteristic zones we see today, such as the subalpine forests dominated by red spruce and balsam fir, didn't exist until 3,000 years ago. Before then, red spruce was rare throughout the region, and forests of hardwoods and hemlock bordered high-elevation fir forests. The region experienced different combinations of annual and seasonal temperatures, rainfall, and humidity, which gave rise to new combinations of tree species.

Based on the records from the lake sediments, global warming would not result in a simple upward shift in the current vegetation zones of the Adirondacks. Future climate changes and biotic responses will probably be at least as complex as those of the past 10,000 years. We can expect changes not only in average conditions but also in extremes, such as drought, and in seasonal distribution of precipitation. Changes in the frequency of fires and blowdowns by strong winds could also have a hand in reshaping the forests.

Attempts to preserve characteristic Adirondack community types may be unsuccessful in the face of climate change. Because of its size, however, the Adirondack Park may play a key role in preserving regional biodiversity during the next century. The extensive tracts of undeveloped land connect diverse habitats, providing routes for plant and animal species that will need to adjust their geographic location and form new communities as the climate changes. Elsewhere in the eastern United States, the landscape has been fragmented, and those habitats that have been preserved are isolated, restricting natural adjustment of communities to large-scale environmental change.

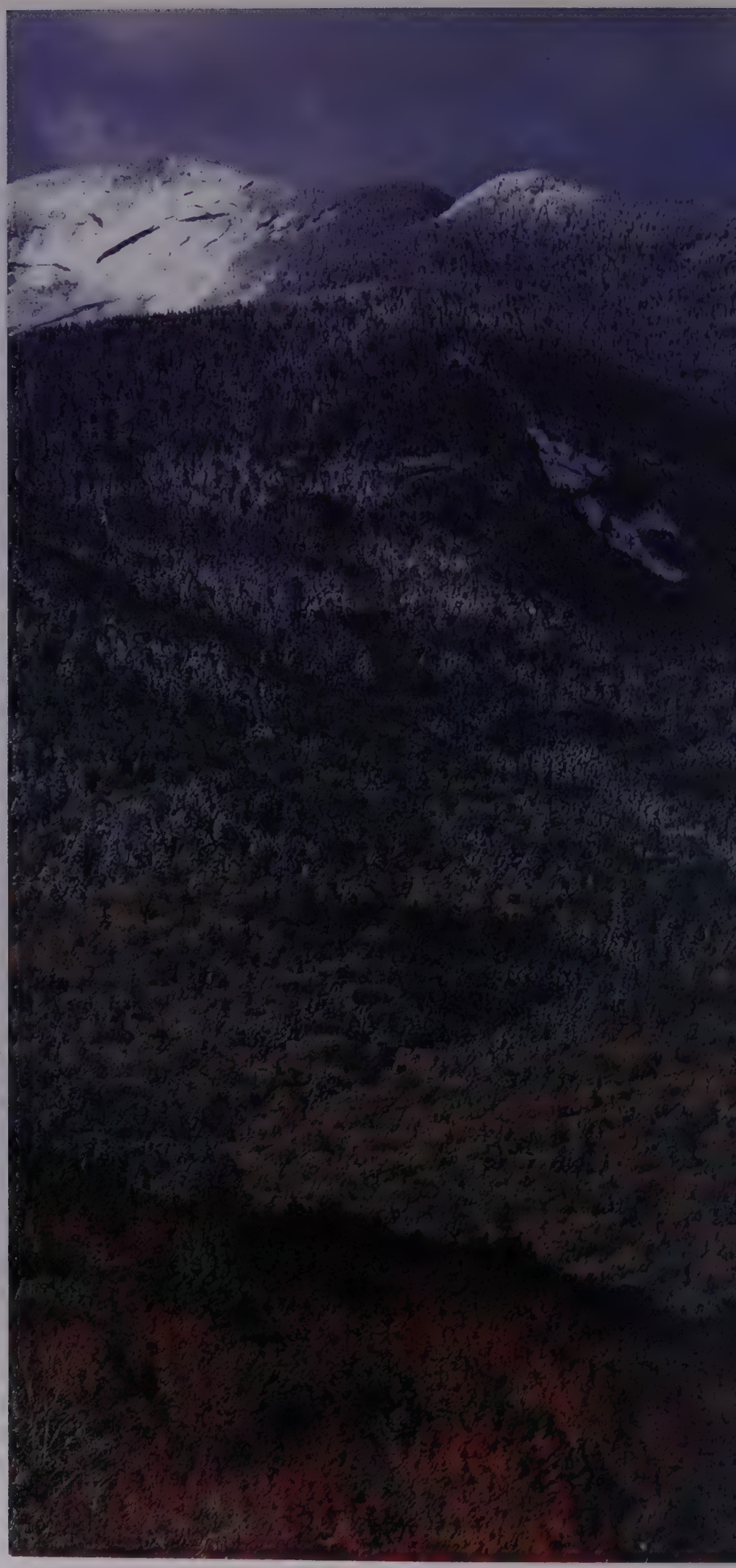
Stephen T. Jackson is an ecologist at Northern Arizona University.

Gothics, Armstrong, and Upper Wolfjaw mountains (left to right) in the Adirondacks' "Great Range"
Clyde H. Smith; Peter Arnold, Inc.

act that would have freed funds for new conservation land. Now, even though land is available at bargain prices because of the recession, there's no money to snatch it up. The remaining parcels, which would finally link the current wildernesses and make the park a biological masterpiece, may instead be developed for second homes when the economy revives.

State conservation officials continue to go through the motions, working with local residents and environmental groups to identify key properties that might be acquired should the state ever recover financial health, but the frustration level is high. Partly it's because there's no guarantee the Adirondacks will ever be a state priority again. A hundred years ago they were one of the great tourist attractions in the New World, but now New Yorkers can drive to LaGuardia and visit the Bahamas as quickly as they can reach the base of Mount Marcy. (And there are no black flies in the Bahamas.) To many in the state, Alaska's Wildlife Refuge or the old-growth forests of Oregon seem more real—they simply can't imagine that big wilderness actually thrives four hours from Co-op City. The Adirondacks provide concrete benefits to the state—they were originally protected to preserve the headwaters of the Hudson, a task that remains important. But in many ways the most vital role of the region now is as a reminder and a beacon—a place where life is still tied to the land, a place that is dealing seriously with the conflicts between people and nature. Which are, of course, precisely the conflicts reasserting themselves around the world as we enter this moment of environmental peril. Lab and experiment both, the Adirondacks should be as much a symbol of New York's contribution to the world as the statue in the harbor proclaiming liberty.

So while it's true that in this centennial year the park is in trouble, it's also true that the park has almost always been in trouble. With hindsight, we can recognize how lucky it was that a group of influential people in the 1890s were able to begin the long, slow process of protection, of creating a wilderness on the edge of the eastern megalopolis. Now their ecological vision has been proved correct. We inherit the task of rounding out their creation and of proving something ourselves: that people can still lead decent lives in the same places that beavers and pine trees and moose are leading theirs. □



Earth's Hot Topic

How would you design a major exhibition about an unintentional global experiment with the earth's atmosphere, whose outcome will not be clear until the next century? That was the challenge posed three years ago to a special task force of scientists and exhibition staff at the American Museum of Natural History and their colleagues at the Environmental Defense Fund, a national environmental organization. Drawing advice and information from dozens of specialists and consulting the latest scientific reports, the team has created a 7,000-square-foot exhibition entitled "Global Warming: Understanding the Forecast."

The $3.4 million effort, opening May 15 at the Museum, presents evidence of extreme climate changes in the past, shows how warming of just a few degrees would affect oceans, urban life, and agriculture, and demonstrates the choices facing us today if we want to change the predicted climatic trend.

Global Warming: Understanding the Forecast premières at the American Museum of Natural History on May 15 and runs through January 17, 1993. The exhibition then travels to Los Angeles, Washington, D.C., and other cities.

"Most exhibits in the Museum document events that have happened in the past; we're showing what may happen in the future," said Eva Zelig, exhibition developer for the Museum. "And we also wanted to show science in action," added Stephanie Pfirman, the Environmental Defense Fund's scientific coordinator for the exhibition, who worked closely with Zelig. "One thing we wanted to make sure of was that the exhibition informs the public without glossing over the complexities of the issue. We want to give the facts, but this exhibit—like science itself—is a mixture of data, theory, ideas, interpretations, and questions."

According to Michael Oppenheimer, a scientist at the Environmental Defense Fund, "We know that certain gases trap heat, and that human activities are adding more of them to the atmosphere. Venus is much hotter than Earth not only because it's closer to the sun but also because of the great density of carbon dioxide there." A greenhouse effect occurs when the sun's rays (short-wave solar radiation) pass through the atmosphere, and the accumulated heat (long-wave radiation) becomes trapped within the gaseous envelope. It is similar to what happens inside a parked car with the windows rolled up, or in a gardener's greenhouse.

A natural greenhouse effect has been generally beneficial to life on Earth, but the effect is being greatly intensified as human activities release immense quantities of otherwise harmless gases into the atmosphere: carbon dioxide from burning forests and fossil fuels, nitrous oxide from fertilizers, and methane from rice paddies, cattle, and fossil fuel production.

Automobiles and industrial processes that burn oil, coal, and gasoline produce the greatest quantities of greenhouse gases. Another major source is the burning of tropical rain forests. Round-the-clock incineration of vast tracts spews enormous quantities of carbon dioxide into the air, while destroying millions of trees that could store the carbon. In all, human activity releases about 26 billion tons of carbon dioxide into the atmosphere yearly; only half that much can be absorbed by oceans and forests.

The United Nations Intergovernmental Panel on Climate Change and the National Academy of Sciences have estimated that average temperatures could rise between three and eight degrees Fahrenheit by the middle of the next century, making the earth warmer than at any time in the past 10,000 years. Climate changes could have wide-ranging implications, with some parts of the world enjoying a new boon in agriculture, while others reap disaster. Some polar ice would melt, raising ocean levels and flooding low-lying populated areas, an outcome dramatized in the exhibition by an interactive display of Washington, D.C., in the year 2050. By pressing a button, visitors can initiate a fiber-optic storm that will cause the Potomac River to inundate the capital.

What else can a visitor see? Near the entrance are reminders that climate has changed drastically in the past, including the fossil of a huge tropical palm frond that grew in Utah during the Cretaceous. To illustrate the scale of glaciation 20,000 years ago, a model shows Manhattan skyscrapers buried beneath massive ice sheets. At that time, the earth had an average temperature only nine degrees Fahrenheit colder than it is today—about the same difference as predicted for 2100, although in the opposite direction. Displayed in a special refrigerated glass case, Greenland ice cores formed 600 years ago contain trapped bubbles with a much lower level of greenhouse gases than today's air. Visitors can examine rings from a 2,000-year-old Tasmanian tree and a sediment core from the Arctic Ocean with magnifying lenses to learn how scientists infer ancient climates from such evidence.

Diverse sources of today's greenhouse gas buildup are also represented in the exhibition. One display is the "burping cow," representing the world's 1.3 billion dairy and beef cattle. Like all ruminants, their digestive systems process grasses, expelling methane as a major byproduct. Partly transparent, the cow's "gut" lights up at intervals. Each pulse of light activates a meter that registers a release of methane, accompanied by realistic sounds of bovine burps.

Visitors can see for themselves how scientists come up with climate predictions on screens that convert mathematical models into colorful graphic images. Interactive exhibits on climate systems show what the role of clouds, plants, oceans, and other factors might be in shaping future climate. Scientists are not yet sure how clouds and ocean currents will react to global warming; these unknown variables

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UNDERSTANDING THE FORECAST

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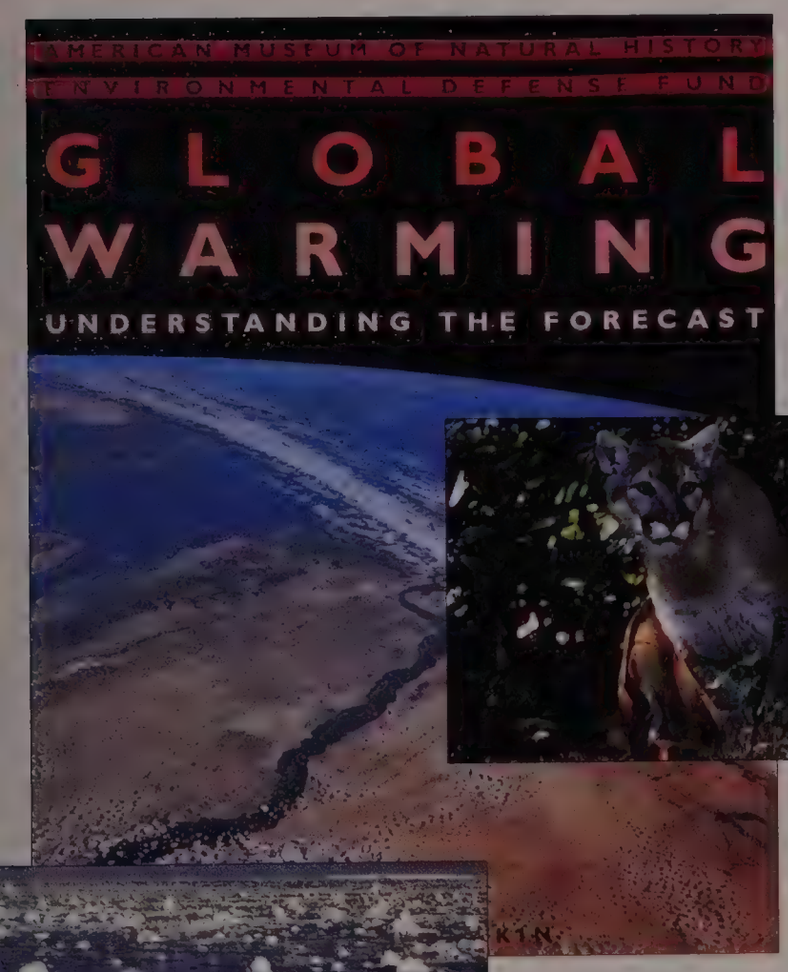

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may confound computer predictions.

In another interactive exhibit, visitors can choose alternative future scenarios. A visitor could decide to reduce carbon dioxide by a certain amount, for instance, and immediately see the results projected on world maps. These exhibits demonstrate how models of global climate are constructed, but as Oppenheimer puts it, "We can see the vague outlines with computer simulations, but these are not accurate predictions; they indicate a direction of change and also serve to underscore uncertainties." An overall trend of the last century has been an increase in atmospheric temperature of nearly one degree Fahrenheit. While the 1980s was the warmest decade in a century, scientists cannot yet tell how much of that warming was directly caused by the increase in greenhouse gases. (There are always short-term, random highs and lows in global temperature.)

Global warming could undermine the work of conservationists to save thousands of species of animals and plants. One three-dimensional display shows a protected stand of jack pine forest in Michigan, the only nesting grounds of the endangered Kirtland's warbler. Only a few degrees of warming would change the habitat, rendering the sanctuary useless to the birds. Another diorama shows the salt marsh on the Texas coast where the only wild breeding population of 150 whooping cranes spends the winter. Then, through an arrangement of lights and mirrors, the scene fades out and is replaced by a possible future scenario: the refuge flooded.

Museum paleontologist Malcolm McKenna, another adviser to the exhibition, has discovered crocodile and tapir fossils near the North Pole, which has given him a special appreciation for the impact of climatic shifts. "Humans, whether we know it or not and whether we like it or not, are participating in a giant experiment in climatic change," he said. "We are part of the system we are changing, not outside of it. Scientists need to make the public aware that it's like rowing a boat when a dangerous rapid looms ahead; early minor adjustments might save a lot of frantic activity later on."

To research the level of public awareness of global warming, the exhibition's planners conducted surveys among Museum visitors. Many thought global climate was being heated up by the widening hole in the ozone layer. (Actually, they are separate problems, and the relationship between them is still being studied.) Others asked what they could do to help prevent planetary warming. In one section of the exhibition, individuals can test their own "scores" in their choices of transportation, food, and products to learn whether they are part of the global warming problem or part of its solution.

Some scientists, like Wallace Broecker, a professor at Columbia University, have argued that global warming is only one part of a very complex problem. Broecker insists that one cannot address any environmental issue *in vacuo,* without confronting the time bomb of human population. "Almost every problem we have on the globe is made worse by having more people," he says. "By far most of them are going to be born into poor countries, and they're going to live in already overcrowded, energy-inefficient cities. The real question is what kind of planet it will be with 11 billion people on it by the middle of next century." As a result of Broecker's input, the exhibition has incorporated information about the perils of the population explosion. However, Pfirman says her research on the exhibition has modified her views on that question. "I used to think it was a matter of absolute numbers of people," she says, "but now I see that relative consumption is equally important. An American's life style consumes as much energy as do thirty people in a developing country. Cutting back on energy expenditures by millions of people could make a serious contribution toward stabilizing global climate."

Fred Krupp, the director of the Environmental Defense Fund, hopes the exhibition will move those who see it. "This country wastes vast amounts of energy," he says, "and it is the world's number one emitter of carbon dioxide. We can make our economy leaner, both financially and in terms of reducing pollution, by going toward energy efficiency. Even if we were to stabilize population at today's levels, if people around the world came up to the consumption level of the United States we'd all be sunk. As I see it, we have to get the American public ready to make some tough choices."

Richard Milne

At the American Museum

San Francisco's Old Chinatown

On display in the Akeley Gallery through June are photographs by Arnold Genthe showing San Francisco's Old Chinatown before its destruction in the earthquake and fire of 1906. Four lectures and two films on documenting ethnicity will also be presented, and a play about Chinese settlers in California will be performed. For details, call (212) 769-5315.

Asian/Pacific Month

In May, the Museum celebrates Asian/Pacific Month with free programs. Among the presentations are excerpts from Cantonese opera, music and dance from the Philippines, and Indian classical dance. Lecture topics will cover New York City's Chinese hand laundrymen, the Korean American community, Philippine cuisine, and *Deepavali,* the Indian festival of lights. For more information, call (212) 769-5315.

The Santana Fossils

Since 1817, when Europeans began exploring the region, the Araripe plateau in northeastern Brazil has yielded well-preserved fossils about 110 million years old. An exhibit displaying these diverse finds, as well as habitat re-creations, opens on Friday, May 1, in the Roosevelt Rotunda. Through the philanthropy of Herbert R. Axelrod, president of TFH (Tropical Fish Hobbyist) Publications, part of the plateau has been set aside as paleontology's first conservation site.

At the Planetarium

Weather and climate will be the theme on National Astronomy Day, Saturday, May 2. Related activities will be held throughout the day. In addition to regular sky shows, "Wonderful Sky," featuring the Sesame Street Muppets, will be shown at 10:30 and 11:45 A.M.

Richard Tresch Fienberg, president and CEO of Sky Publishing Corporation, will give an illustrated talk on the astronomy initiatives proposed by the National Academy of Sciences for the 1990s. The lecture, on Tuesday, May 19, at 7:30 P.M. in the Sky Theater, is part of the "Frontiers in Astronomy and Astrophysics" series. Tickets are $6 ($5 for members). For more information, call (212) 769-5900.

Hominoid Jawbone Discovery

The fossil jawbone of *Otavipithecus,* a newly discovered species of prehuman, will be on display in the third-floor Primate Hall beginning Tuesday, March 31. A joint American-French paleontology team made the find last summer in an abandoned mine dump in Namibia. The exhibit will also feature other fossils from the deposit that helped date the jawbone.

These events take place at the American Museum of Natural History, located on Central Park West at 79th Street in New York City. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

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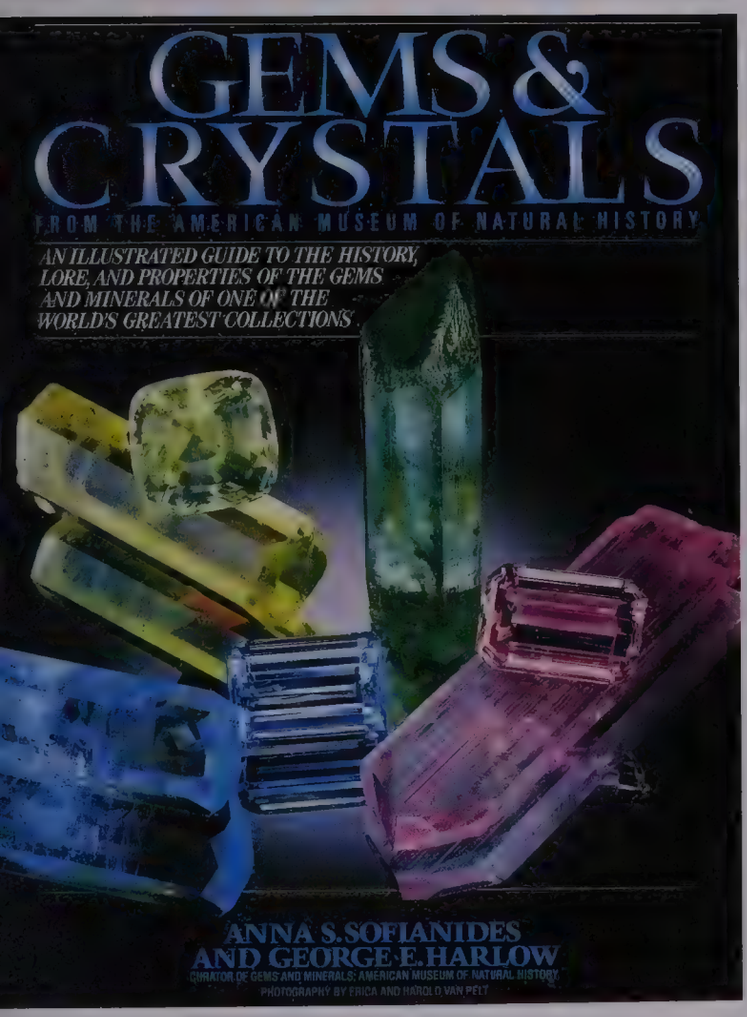
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Milch Ewe Millennium

Will high-tech sheep breeding yield an American Roquefort?

by Raymond Sokolov

At one point in time in the 1980s, two women expatriates leading glamorous lives in London were thinking a lot about sheep. For most people, sheep are so unstimulating that we count them at bedtime in order to bore ourselves to sleep, but for these two female cosmopolites, sheep were exciting enough to keep them up nights. Sheep were an inspiration.

María José Sevilla wrote a book about the sheep-centered world of her people. Joan Snyder left her job at Merrill Lynch International and set up a sheep cheese creamery in the Hudson Valley about two and a half hours north of New York City. For Sevilla, her book was a logical extension of her Basque heritage and her professional life as the Spanish government's culinary missionary to the United Kingdom. For Snyder, her training as a merchant banker led her to conclude that producing cheese from sheep's milk was the best way to make an income from the 200-acre farm she had bought in northern Columbia County.

Both women found themselves leaving behind highly urban careers to explore a form of rural life based on a primitive and primordial activity, the herding of sheep. Sevilla's research was not, of course, limited to the pastoral side of Basque gastronomic life. She also looked into Basque fishing, Basque markets, Basque farmhouse cookery, Basque cider, Basque eating societies, and even the sophisticated heights of Basque nouvelle cuisine, *la nueva cocina vasca.* But the most central—and the most traditional—side of Basque foodways that she recorded was the nomadic life of shepherds pasturing their flocks in the high meadows of the Pyrenees, keeping them safe and well-fed in return for their wool, meat, and milk.

In the market at Ordicia, a weekly affair since 1798, Sevilla found the arcades full of small stalls selling sheep cheeses, many of them made in shepherds' huts and brought down to town by their wives and daughters. There is pungent smoked cheese from the Valle del Roncal, to be eaten at the end of a meal. Others are yellow from being smoked with fresh-felled wood; Idiazabals, or those from the Sierra de Aralar, are cylindrical and weigh two to three pounds. There are also the Baztán cheeses—eaten with aperitifs, added to soup, melted into the corn bread called *talos.* And all of them are made from sheep's milk, often in the same way that shepherds made cheese in biblical days and in the days of Homer.

Between the months of May and November, José Martín is alone with his sheep, he rises at six or seven o'clock each morning and, after a light breakfast of goat's milk and a little bread, goes out to milk his flock. Sometimes they have slept in the fold, at other times he has to go and find them and pen them in before milking. The warm milk squirts loudly into the plastic bucket as the shepherd squeezes the ewes' teats.

As soon as he gets back from milking, José Martín sets about making the cheese. The first part of the process is to filter the still tepid milk. If the milk has cooled down too much he warms it gently to about 25° C [77° F]. In the mountains the shepherds still use natural rennet [a substance scraped from the stomach lining of cows and other ruminants that contains the coagulating enzyme rennin, which precipitates the curdling of milk], which they thin with a little warm water and add to the milk as it is filtered. The mixture is left to stand for three-quarters of an hour and then stirred with the hand or a spoon until the whey begins to separate from the curds. The liquid [whey] is drained off little by little and the curds pushed down to the bottom of a plastic bowl. At this point the curds are cut into the number of cheeses which he wishes to make. Each piece is placed in a [perforated] plastic mold, left for a while and then turned over. Until a few years ago José Martín did everything by hand because he had no cheese press; now he has a small one where the cheese remains for about twelve hours, after which it is passed through a *salmuera* or brine solution, and then left for another twelve hours. Some shepherds simply cover the surface of the cheese with salt. Once they have been salted the cheeses are placed on some boards where they are left for about two months, before being sold [*Life and Food in the Basque Country,* by María José Sevilla. New Amsterdam Books, 1990].

Very traditional Basque cheese makers milk sheep into a handmade wooden (birch) pitcher called a *kaiku,* which is also used for cooking. Pebbles heated in a campfire (*kaikuarris*) are placed in the *kaiku,* where they give a sought-after burned taste to milk used for a fruit junket known as *mamia.*

Perhaps the persistence of wood vessels in some places does contribute to the character of Basque cheeses, as well as linking them in the imagination to prehistoric days when Basques had not yet learned the art of making earthenware vessels. At any rate, Sevilla mentions other refinements that clearly do matter. For example, the breed of the sheep. Rasa sheep from the Valle del Roncal produce a dry cheese, while the Latxa sheep of the Baztán valley are admired for white, creamy cheese, best when young.

In those fast-disappearing farmsteads and huts where the old ways continue, the funnel-strainer (*idaztia*) for the fresh milk is lined with nettle leaves to remove impurities and hooked onto a two-handled pail (*abatza*). The curdled milk is stirred with a spoon (*malatza*). The perforated mold (*zumitza*) is carved with geometric figures that impress themselves on the cheese as it drains onto a board (*kartola*).

Most of us will never taste one of these cheeses, but in the ever-improving world of U.S. food retailing, factory versions are now available from Basque producers in both Spain and France. The variety is impressive, but these cheeses are only one part of sheep cheese making. Italians make pecorino and romano. Some Greek fetas are ovine. And in central Spain, La Mancha manufactures tons of manchego.

The most famous of sheep cheeses is Roquefort, the crumbly, blue-green penicillin-mold masterpiece. But even Roquefort seems to be threatened by the pres-

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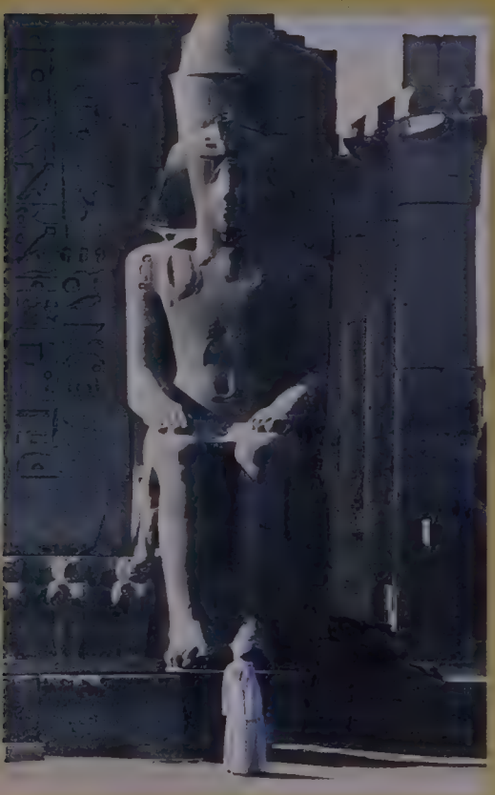

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sures of modern life. Protected until now by a cozy arrangement of fixed high milk prices for local sheepmen and a shrewdly defended standard of quality, Roquefort is, in effect, a monopoly cooperative run by Société des Caves et des Producteurs Réunis de Roquefort. But that company is controlled by Source Perrier, the mineral-water outfit, which as of this writing is itself a target for takeover by Nestlé and Fiat. And now that Europe is Europe, there isn't much that Roquefort traditionalists can do to ward off control by foreigners partial to chocolate or Gorgonzola. Worse still, from the local sheep raisers' point of view, new owners might not keep up the milk price subsidy that has encouraged Roquefort sheepmen to breed sheep that are superlative milkers. As a result of this arrangement, Roquefort has a serious sheep milk surplus.

Don't mention that to Joan Snyder. Or her partner, the former journalist and guitar pedagogue Ken Kleinpeter. Their sheep cheese operation at Hollow Road Farms in Stuyvesant, New York, is in desperate sheep-milk deficit. That's because American sheep were not historically bred as dairy animals. Our sheep were raised for wool and meat.

So a typical U.S. ewe, during her 100 or so days of lactation, will average a quart of milk a day. Triple that would be an average output for a European milch ewe, according to Kleinpeter, who tends pregnant sheep immobilized with triplets as if he had been doing it all his life. He and Snyder can currently fill only a quarter of the orders they receive from restaurants and gourmet food stores. When I visited them in midwinter, the low end of their production year (lambing peaks in the spring), there was almost no cheese on hand.

The obvious solution for them would be to buy high-yield milkers from Roquefort or Spain. But that's against the law. The only sheep that can be imported here are sheep from countries declared free of a deadly virus called scrapie. As it happens, the only officially scrapie-free countries are Australia and New Zealand, and they don't have milch ewes. The scrapie embargo also keeps out frozen embryos and sperm. So Snyder and Kleinpeter, as well as the handful of other American sheep cheese pioneers, scrape around for milk and breed for the future.

Since the mideighties, Snyder and Kleinpeter have screened about 1,000 ewes and bred them selectively, with the help of a computerized genetic data base. That huge effort has identified twenty-five to thirty super producers, ewes up to the average standard of European dairy ewes. At this rate, it would take many years, well over a decade, to engender enough optimal milkers to maintain the herd size they want: 300.

So this year, they hope to speed up the breeding program with a sort of high-science form of ovine surrogate motherhood. Reproductive hormones will induce hyperovulation in the superproductive milkers, and the extra embryos will be implanted into "inferior" ewes. This should quadruple the rate of birth of superior milkers. By 1994, Hollow Road Farms will have increased the average productivity of its milk herd by 50 percent, and by 1995 or 1996, the increase should reach 100 percent.

The implications, nationally, are also significant. For the first time, this country would have a large herd of high-quality milch ewes, a herd capable of supplying other dairy operations around the country with milch ewes of their own. And then an American sheep cheese industry would be a practical reality.

Perhaps the need for such a thing is not immediately obvious. After all, there is a lot of imported sheep cheese available for those who want it, and it's doubtful that U.S. producers will ever be able to market a significantly cheaper hard sheep cheese as long as European exporters subsidize their industry. That was my view until I tasted some of the remarkably rich and mild milk that Hollow Road Farms sheep are producing.

Sheep's milk is decidedly richer than either cow's or goat's milk. Here is Hollow Road Farms' comparison based on eight ounces of milk:

	Sheep	Goat	Cow
Calories	191	168	156
Calcium	568mg	327mg	290mg
Cholesterol	48mg	27mg	34mg
Protein	12.8g	7.5g	7.4g
Fat	11.0g	10.1g	8.9g

These figures may not encourage weight watchers and atherosclerotics to indulge in large amounts of sheep dairy products, but the richness and sweetness of this milk is responsible for the taste of the yogurt, which is a revelation: luxurious and mild, no goatish fatty-acid aftertaste. The same is true of the gently tangy fresh cheeses. And the fresh-ripened, Camembert-style cheese made from a mix of sheep and cow milk is an original, delicate creation.

These fresh, perishable products do not face serious competition from their European counterparts. Yogurt is not importable by law because it is classified as a fluid dairy product, and fresh cheeses tend to stay at home because they are so

nort-lived. So yogurt and fresh cheeses re what we are likely to see from U.S. roducers in the near future. Nevertheess, the chauvinist in me hopes that with ne millennium will come a blue-green nold sheep cheese made in the U.S.A. An American Roquefort. Manufacture will e centered in Rockford, Illinois.

The very thought makes me want to leat with joy.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

Two recipes employing feta cheese, from Arthur Schwartz's *What to Cook When You Think There's Nothing in the House to Eat,* HarperPerennial, 1992

Saganaki

2 tablespoons butter
4 ounces feta, sliced
Juice of ½ lemon
1 tablespoon brandy (optional)

1. In a small skillet, heat the butter over medium heat until it sizzles.
2. Add the feta and fry 2 minutes on each side, until melted and lightly browned.
3. Squeeze on the lemon juice and eat immediately. Or pour on the brandy, ignite, and when the flames go out, sprinkle on the lemon juice and eat.

Yield: 1 serving

Butter unquestionably adds to the appeal of the cheese, but feta is also good melted under a broiler or in a toaster oven, on bread or not, with lemon juice or not.

Macaroni and Cheese Like a Greek Salad

¼ pound macaroni
1½ tablespoons fruity olive oil
1 tablespoon wine vinegar
2 ounces feta (¼ most supermarket packages)
4–5 Kalamata or other Greek olives, pitted and quartered
¾ teaspoon dried Mediterranean oregano
Freshly ground pepper

1. Cook the macaroni until tender. Drain well.
2. Pour into a mixing bowl and toss immediately with the oil.
3. Add vinegar and toss again.
4. Add the feta, olives, oregano, and several grinds of the pepper mill. (Because the cheese is salty, additional salt is probably not necessary.) Toss again. Serve hot or at room temperature.

Yield: 1 or 2 servings

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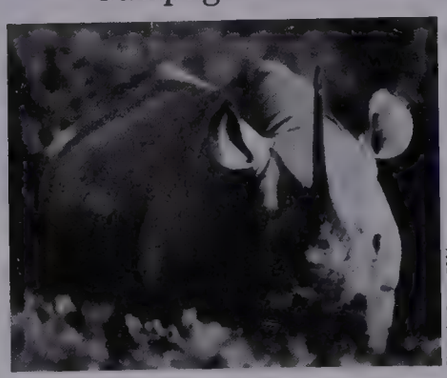

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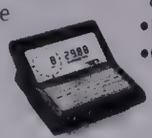

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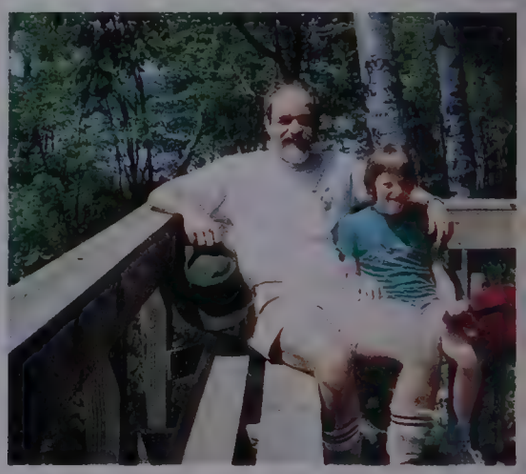
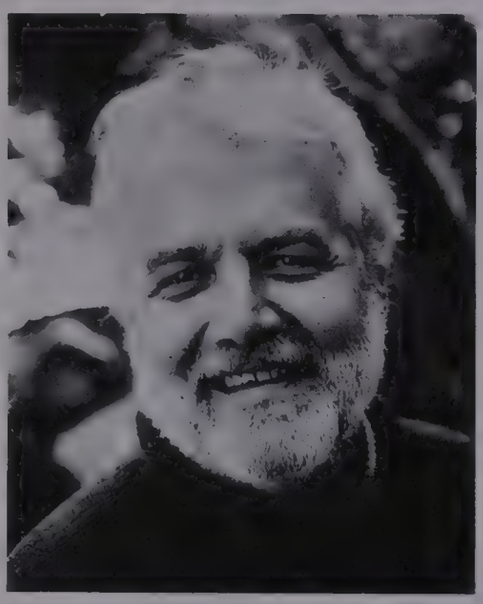
Secure under the sheltering leaf, the eggs are protected from strong sunlight, foraging birds and snakes, and a host of aquatic predators—beetles, dragonfly nymphs, turtles, and fish. Only the chunk-headed snake overcomes this passive defense, being well adapted to climb the floppy leaves in search of frog spawn. Once in the water, the mobile tadpoles stand a better chance of eluding hungry neighbors in the swamp than would an inert egg mass. But the sheer number of tadpoles hatching at once also insures that even though some will perish, many others will survive, sprout legs, mate, and spawn at the onset of the next rainy season.—*J. R.*

Photograph by George Bernard NHPA

Right after graduating from high school in 1966, **Philip G. Terrie** (page 28) worked at an Adirondack summer camp, where he fell in love with the wilderness. After attending Princeton, he returned to the mountains to work at the Adirondack Museum. For his doctoral dissertation in American studies at George Washington University, Terrie chose the history of the idea of wilderness in the Adirondacks, which became the core of his book *Forever Wild: Environmental Aesthetics and the Adirondack Forest Preserve* (Philadelphia: Temple University Press, 1985). Now an associate professor of English and American culture studies at Bowling Green State University in Ohio, his interests have broadened to include all American environmental history and literature. Still, he remains obsessed with the Adirondacks. Shown here with his daughter, he and his family regularly summer at their cabin on Long Lake, six miles from the nearest road. In addition to studying Adirondack history, Terrie enjoys backpacking, hiking, and canoeing—"any excuse to get into the backcountry."





In eleven novels and numerous poems, stories, and essays, **Russell Banks** (page 26) has evoked a powerful sense of place. And each place he has lived, from New Hampshire to North Carolina to Jamaica, invariably works its way into his books. Banks first went to the Adirondacks in 1987 at the urging of his wife, whose family has summered there since the nineteenth century. "It was very much like a return to the northern New England of my childhood in the 1940s." Now, Banks divides his time between Princeton University, where he teaches creative writing, and the town of Keene in the Adirondacks, which he has used as the setting for his latest novel, *The Sweet Hereafter.*

Yngvar W. Isachsen (page 31) has focused on the geology of the Adirondacks for most of his career. He received his Ph.D. from Cornell University in 1953, for his mapping of the geology of the northwestern part of the mountains. After a five-year hiatus, during which he explored for uranium deposits on the Colorado Plateau, in Colombia, and in Turkey, Isachsen resumed mapping the Adirondacks and drew up the first geological map of the region published since 1901. In the early 1970s, after many field seasons tracing the geology from outcrop to outcrop—the nuts and bolts of the science—he turned his attention to larger questions: When and why were the Adirondacks uplifted? Currently, Isachsen is the principal geologist at the Geological Survey of the New York State Museum and an adjunct professor at Rensselaer Polytechnic Institute. He enjoys camping and canoeing in the mountains, where he and his family have built a camp on Brant Lake.

Except for military service during World War II and Ph.D. work at Stanford University, **Edwin H. Ketchledge** (page 34) has spent his career working on Adirondack natural resources and natural history at the State University of New York College of Environmental Science and Forestry, Syracuse. "I have watched wilderness return over the course of sixty years roaming and studying the Adirondacks, both as a professional forest ecologist and as a citizen forest recreationist." Now retired, Ketchledge remains an indefatigable Adirondack activist, especially for the conservation of rare ecosystems on high alpine summits.

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In the late 1960s, **Anne LaBastille** (page 42) built her own log cabin and took up residence on a remote Adirondack lake; later, she became a registered guide. A writer and photographer, LaBastille also earned a doctorate in wildlife ecology from Cornell University. The author of two books on her early wilderness and guiding experiences, *Woodswoman* and *Beyond Black Bear Lake,* LaBastille is now the president of West of the Wind Publications, Inc., and a commissioner of the Adirondack Park Agency. She has studied the effects of acid rain in the Adirondacks and has spent part of each of the last twenty-five years in Guatemala. She called attention to the plight of the endangered giant grebe of Lake Atitlan in her article "Goodbye, Giant Grebe?" in *Natural History* (February 1983) and in her 1990 book, *Mama Poc.* Her latest collection of writings is *The Wilderness World of Anne LaBastille,* to be published this month by West of the Wind.

Growing up in India, **Rainer H. Brocke** (page 50) says he was privileged to observe large predators such as tigers and leopards in their natural surroundings. Later, on coming to the United States, he was delighted to find a healthy and interesting complex of predators here, too. In the Adirondacks, Brocke, left, shown here with graduate student Gary Brundige, has concentrated on the coyote, the region's second largest wild predator (next to the black bear). Brocke, an associate professor at the State University of New York College of Environmental Science and Forestry, Syracuse, is also involved in an ongoing project to restore lynx to the park.

Wild turkeys of the upper Mississippi Valley were the first focus of **William F. Porter**'s interest in the relationship between habitat, animal behavior, and population ecology (page 48). He moved to Syracuse in 1978 and has been a member of a long-term deer research team in the Adirondacks since 1980. As a professor at the State University of New York College of Environmental Science and Forestry, Syracuse, and director of the Adirondack Ecological Center, Porter also oversees graduate students working on deer (in New York and the Cape Cod National Seashore), moose (in Ontario), and wild turkeys (in central New York).

Dietland Müller-Schwarze (page 52) is a professor at the State University of New York College of Environmental Science and Forestry, Syracuse. Originally from Germany, he has been studying Adirondack beavers since 1974. His primary research interest is the animals' chemical ecology. Beavers use phenolic and other chemical compounds, derived from the plants they eat, to produce castoreum, a smelly paste with which they mark their family territories (and which humans have long used in the manufacture of perfume). Müller-Schwarze doesn't spend all his time in pursuit of beaver pheromones, however. Over the last seven years, he has climbed all of the Adirondacks' forty-six High Peaks (mountains more than 4,000 feet high), all with his family.

Peter Nye (page 54) began watching bald eagles in 1976 while working for the New York State Department of Environmental Conservation. A wildlife biologist, Nye now heads the Endangered Species Unit of the New York State Division of Fish and Wildlife. These species include local ones, such as the Karner blue butterfly, Allegheny wood rat, and Chittanango snail, as well as peregrine falcons and bald eagles. Nye has spent eight summers in southeastern Alaska surveying and collecting eaglets for relocation in New York, and has also helped other states with their bald eagle reintroduction programs.

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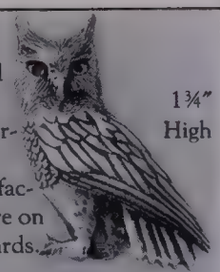

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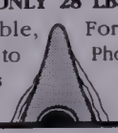

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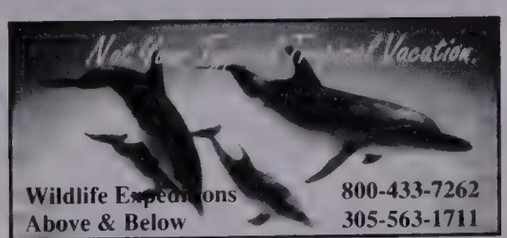

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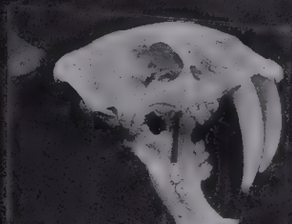

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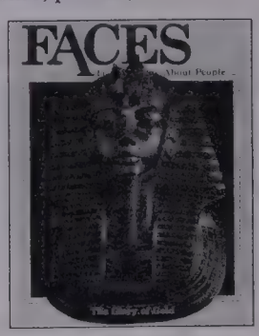

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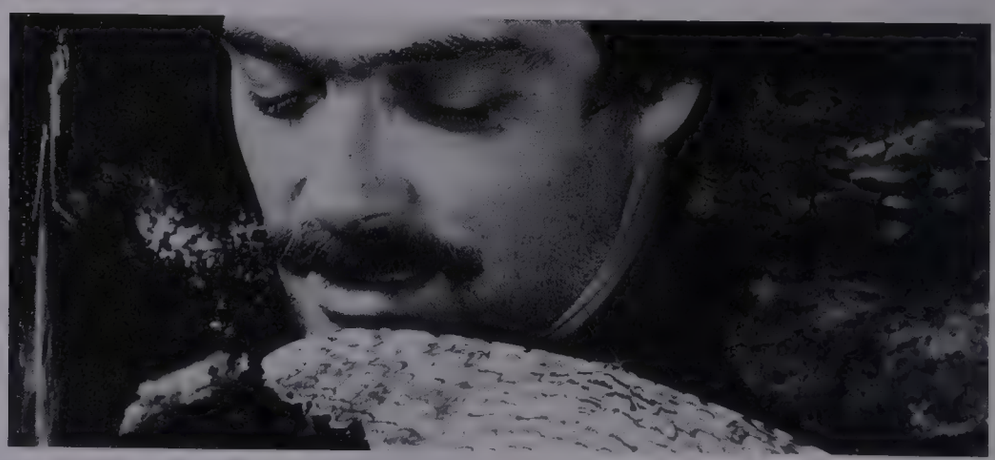
After completing her doctorate at the University of Minnesota, **Judith W. McIntyre** (page 56) moved to New York State, where she is now a professor of biology at Utica College of Syracuse University. For twenty-five years, she has studied common loon vocalizations in Saskatchewan and Minnesota, wintering loons off the coast of Virginia, and yellow-billed loon distribution on the North Slope of Alaska. In a long-term study of Adirondack loons, McIntyre has investigated conflict between people and loons and the impact of environmental change on breeding loons. She is the author of *The Common Loon: Spirit of Northern Lakes* (Minneapolis: University of Minnesota Press, 1988).

Bill McKibben (page 58) graduated from Harvard College in 1982 and almost immediately launched a professional writing career by becoming a staff writer for the *New Yorker,* where he remained for five years, contributing numerous articles. His first book, *The End of Nature,* appeared in 1989 and has since been published in sixteen languages. For his forthcoming book, *The Age of Missing Information,* McKibben found the largest cable TV system in America and got tapes of every program that ran on its hundred channels for a single day (nearly 2,000 hours of tape). "Then I spent a year watching it," he says, "asking myself, what would the world look like if this was my main source of information about it? And how would my outlook differ if I spent a day instead on top of an Adirondack mountain and drew my lessons from that experience? It's as close as I'm likely to come to a scientific experiment." McKibben lives with his wife and dog in the Adirondack Mountains, where he teaches Sunday school in the local Methodist church and is treasurer of the volunteer fire department.

During the first week of May 1989, **George Bernard** (page 74) set up his camera in a Central American swamp to capture the midnight release of tree frog tadpoles from their egg mass. Great numbers of tadpoles hatch out synchronously when the rainy season begins. A native Scot, Bernard studied biological sciences at Aston in Birmingham, England. He became interested in both Latin America and photography in the 1970s, when, on a field trip, he discovered a new species of butterfly. Bernard worked for five years as a photographer for Oxford Scientific Films and has taken part in expeditions to Zimbabwe, the Andes, Venezuela, Bolivia, and Central America. He shot this month's "Natural Moment" with a Nikon camera and a 105mm macrolens.



Additional Reading

For more Adirondack-related reading, our authors recommend the following:

Coyotes: Biology, Behavior, and Management, edited by Marc Bekoff. *Academic Press, 1978.*

Defending the Wilderness, by Paul Schaefer. *Syracuse University Press, 1989.*

The American Beaver: A Classic of Natural History and Ecology, by Lewis H. Morgan. *1868 version republished by Dover Publications, Inc., 1986.*

Adirondack Pilgrimage, by Paul Jamieson. *Adirondack Mountain Club, 1986.*

Adirondack Country, by William Chapman White. *Syracuse University Press, 1984.*

Lumberjacks & Rivermen in the Central Adirondacks, 1850–1950, by Harold K. Hochschild. *Syracuse University Press, 1962.*

Recording: *Voices of the Loon,* by William Barklow. *Guilford, NH: North American Loon Fund, 1980.*

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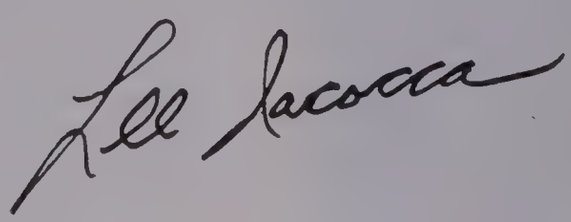

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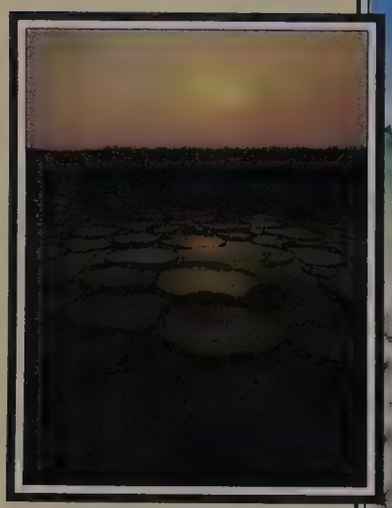

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Bagging Game

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When it's a weird and usually well-camouflaged insect.

36 BLOODY KNIFE'S LAST STAND *J. Daniel Rogers*
The army scout knew Custer's rash attack was folly, but loyalty, friendship, and hate drove him into battle.

44 TERNS FOR THE BETTER *Joanna Burger and Michael Gochfeld*
They may be common, noisy, and aggressive, but they are welcome neighbors for black skimmers.

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NATURAL HISTORY (ISSN 0028-0712) is published monthly by the American Museum of Natural History, Central Park West at 79th Street, New York, N.Y. 10024. Subscriptions: $25.00 a year. In Canada and all other countries: $34.00 a year. Second-class postage paid at New York, N.Y., and at additional mailing offices. Copyright © 1992 by American Museum of Natural History. All rights reserved. No part of this periodical may be reproduced without written consent of *Natural History*. Send subscription orders and undeliverable copies to the address below. Membership and subscription information: Write to address below or call (800) 234-5252 if urgent. POSTMASTER: Send address changes to Natural History, Post Office Box 5000, Harlan, IA 51537-5000.

Great Expectations

Will the United Nations Conference in Rio live up to its advance billings?

Thousands of well-meaning representatives of the most destructive species on our planet will gather in Rio de Janeiro in June to decide the fate of the earth. Or at least talk about it.

For life on earth, the current course of human affairs is leading inexorably toward disaster, like a ship on autopilot bearing down on a rocky, storm-swept coast. Strong forces are pushing the Good Ship Earth toward the rocky coast: explosive human population growth, the rising expectations of people everywhere, and economic systems that voraciously consume energy and other resources and then spew out wastes that destroy the life-protecting skies, pollute the precious waters, and contaminate the lands.

The United Nations Conference on Environment and Development, which somewhat grandly calls itself the Earth Summit, convenes in Rio from June 1 to June 12. United Nations officials expect more than 100 heads of government to be there (the attendance of President George Bush is a question mark), along with tens of thousands representing nongovernmental organizations, youth and educational groups, businesses, indigenous peoples, and others.

The Earth Summit will consider two themes that are in many ways incompatible with current economic and social systems: the well-being of the environment and the prosperity of all humankind. The dark side of these two coins is the growing awareness that environmental deterioration or widespread human poverty will lead to future disaster.

The journey to the Earth Summit has been a long one. A major point was the United Nations Conference on the Human Environment at Stockholm exactly twenty years ago, when the nations of the world accepted—in a sense—a responsibility for the biosphere. Recent stepping stones to the Rio conference include the Brundtland Commission's report, *Our Common Future,* in 1987, the Second World Climate Conference in Geneva in 1990, and four Preparatory Committee meetings, the latest one at the United Nations in New York from March 2 to April 3. The optimists among the Earth Summit planners expected this last meeting in New York to come up with a draft of a strong and stirring declaration that would be adopted formally in Rio. They were disappointed. Encompassing twenty-seven principles, the draft that emerged

Man's capability to transform his surroundings, if used wisely, can bring to all peoples the benefits of development and the opportunity to enhance the quality of life. Wrongly or heedlessly applied, the same power can do incalculable harm to human beings and the human environment. We see around us growing evidence of man-made harm in many regions of the earth: dangerous levels of pollution in water, air, earth, and living beings; major and undesirable disturbances to the ecological balance of the biosphere; destruction and depletion of irreplaceable resources. . . .

A point has been reached in history when we must shape our actions throughout the world with a more prudent care for their environmental consequences. Through ignorance or indifference we can do massive and irreversible harm to the earthly environment on which our life and well-being depend. . . .

The natural resources of the earth, including the air, water, land, flora and fauna, and especially representative samples of natural ecosystems, must be safeguarded for the benefit of present and future generations. . . .

Man has a special responsibility to safeguard and wisely manage the heritage of wildlife and its habitat, which are now gravely imperiled. . . .

Demographic policies . . . should be applied in those regions where the rate of population growth or excessive population concentrations are likely to have adverse effects on the environment. . . .

States have . . . the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States. . . .

—Declaration of the United Nations Conference on the Human Environment
Stockholm, June 16, 1972

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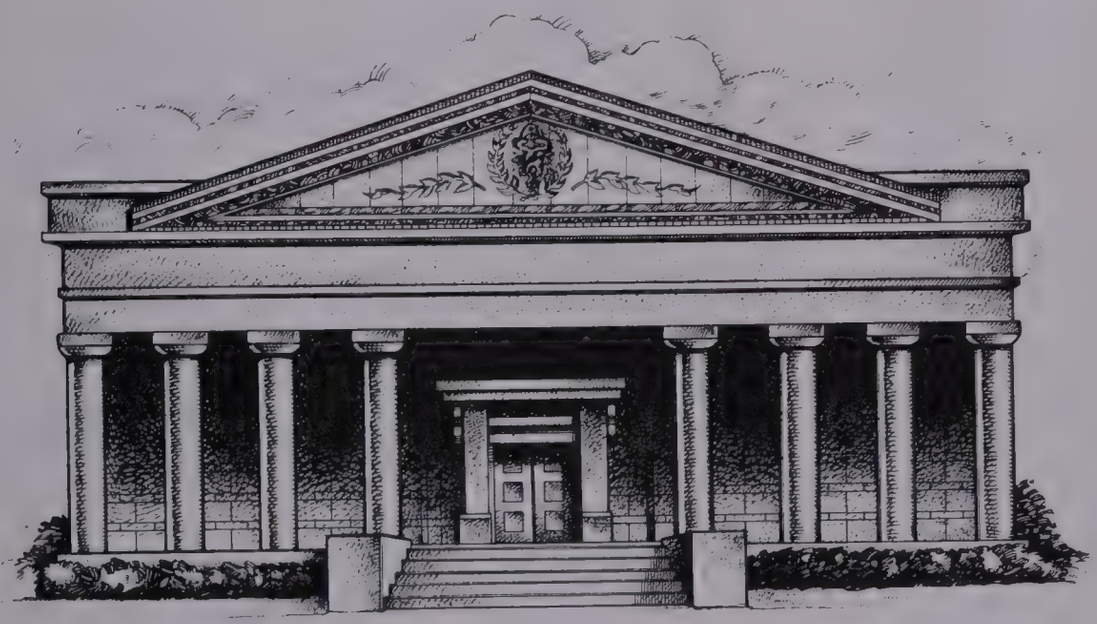

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from the meeting is full of political jargon and compromises. It reflects the special interests of, and great divisions among, the many groups in the global ecosystem, as well as the weak support of such major players as the United States and China. One female observer commented that the conference consisted of "too many men in pin-striped suits."

The Preparatory Conference in New York did take some steps. It reaffirmed the Stockholm declaration (see box on page 4) and recognized "the integral and interdependent nature of the earth, our home." It called for "sustainable development" (jargon for economic activity that does not deplete the environment) and "the essential task of eradicating poverty as an indispensable requirement of sustainable development." The draft touched lightly on principles that have profound implications, such as that "states should reduce and eliminate patterns of production and consumption and promote appropriate demographic policies" and that "the polluter should, in principle, bear the cost of pollution."

Missing from the draft and from other preconference statements were any strong positions on two crucial topics, climate change and the loss of biodiversity (see box above). The conference organizers have hopes that conventions that will commit nations to positive actions in both these areas will emerge from the Earth Summit. Perhaps they will during the twelve-day meeting, but any convention on world climate would be meaningless without the support of the most populated nation (China) and the most polluting one (the United States). Similarly, any agreement on biodiversity needs the backing of the developing countries and the support of the indigenous peoples who live in the tropical forests and other areas of high biological diversity.

Canadian Maurice F. Strong, who is Secretary General for the United Nations Conference in Rio, has been a strong proponent of substantial progress at the Earth Summit (see box below). Strong also headed the Stockholm conference twenty years ago, and he sees the Rio meeting as one step in a process necessary for the "future generations, from whom we have borrowed a fragile planet called Earth." Strong also has gathered support for an Earth Council, an independent body of elder world statesmen who would monitor future environmental developments and actions of countries. It would be a sort of World Court for the biosphere.

Early in June, all roads (well, airplanes) will lead to Rio for dedicated environmentalists, reluctant politicians worried about the green vote, enlightened businessmen, pin-stripe-suited United Nations delegates and officials, representatives of advocacy groups, educators, the media, and many others. The Earth Summit may turn into a meaningless circus with a babble of position papers.

But it may not. The ship of life is moving toward the rocks. Perhaps the Earth Summit will produce commitments from a few honest persons concerned about the future of the biosphere and the generations of humans who will live in it. Perhaps a few elders will push the tiller of the Good Ship Earth a few degrees, and then others will help and the children will join them. It may work. Incidentally, the Good Ship Earth does not carry lifeboats.—*A. P. T.*

Human activity may cause the extinction of more than one quarter of the world's species before the middle of the next century. The catastrophe that may come with this loss is difficult to imagine. Biological species are not simply elements that exist to edify our quest for scientific knowledge or our passion for nature. Each species is connected to others and to the environment, forming the millions of strands of the earth's biosphere. We have barely begun to name the living creatures, much less understand their interactions. The ecosystems of our planet have evolved over thousands, even millions of years, yet we are wantonly destroying vital parts of these systems in decades.

Myriad species are beneficial to humankind in providing food and pharmacological products and in controlling pests and the spread of diseases. For example, the major destruction of natural habitats in India has brought, along with the extinction of many species, the irreparable destruction of more than 20 percent of the land vital to sustaining human populations in that country.

With the projected one billion people to be added to the planet in less than a decade and the concomitant habitat destruction and species extinction that sadly are now part of population growth and industrialization, the future probably will hold even greater suffering and misery.

The United Nations Conference on Environment and Development marks a pivotal moment for the world and its leaders to recognize the scope and irreparable nature of massive biological extinction and for all nations to make a commitment to resolving this global challenge. The biodiversity crisis is not limited to a roll call of snow leopards, elephants, and other treasured species, nor is it restricted to the critical remnants of tropical rain forests. It applies on a global scale to all subdivisions of life and all habitats. The unique and subtle roles particular species play in an ecosystem cannot be duplicated or replaced. Worldwide attention to the problem is long overdue.

—Michael J. Novacek
Dean of Science
American Museum of Natural History

The development model which has produced the life styles that we in the industrialized world and the privileged minority in developing countries enjoy is simply not sustainable. The 1992 Conference will focus largely on the changes we must make in our economic behavior to ensure global environmental security. . . .

What is called for is nothing less than a new "eco-industrial" revolution, one that will not only preserve and extend the benefits created by the industrial revolution, but create a whole new generation of economic opportunity and redress the gross imbalances between rich and poor. . . .

This will require serious examination of the need to extend into the international arena the rule of law and the principle of taxation to finance agreed actions which provide the basis for governance at the national level. . . .

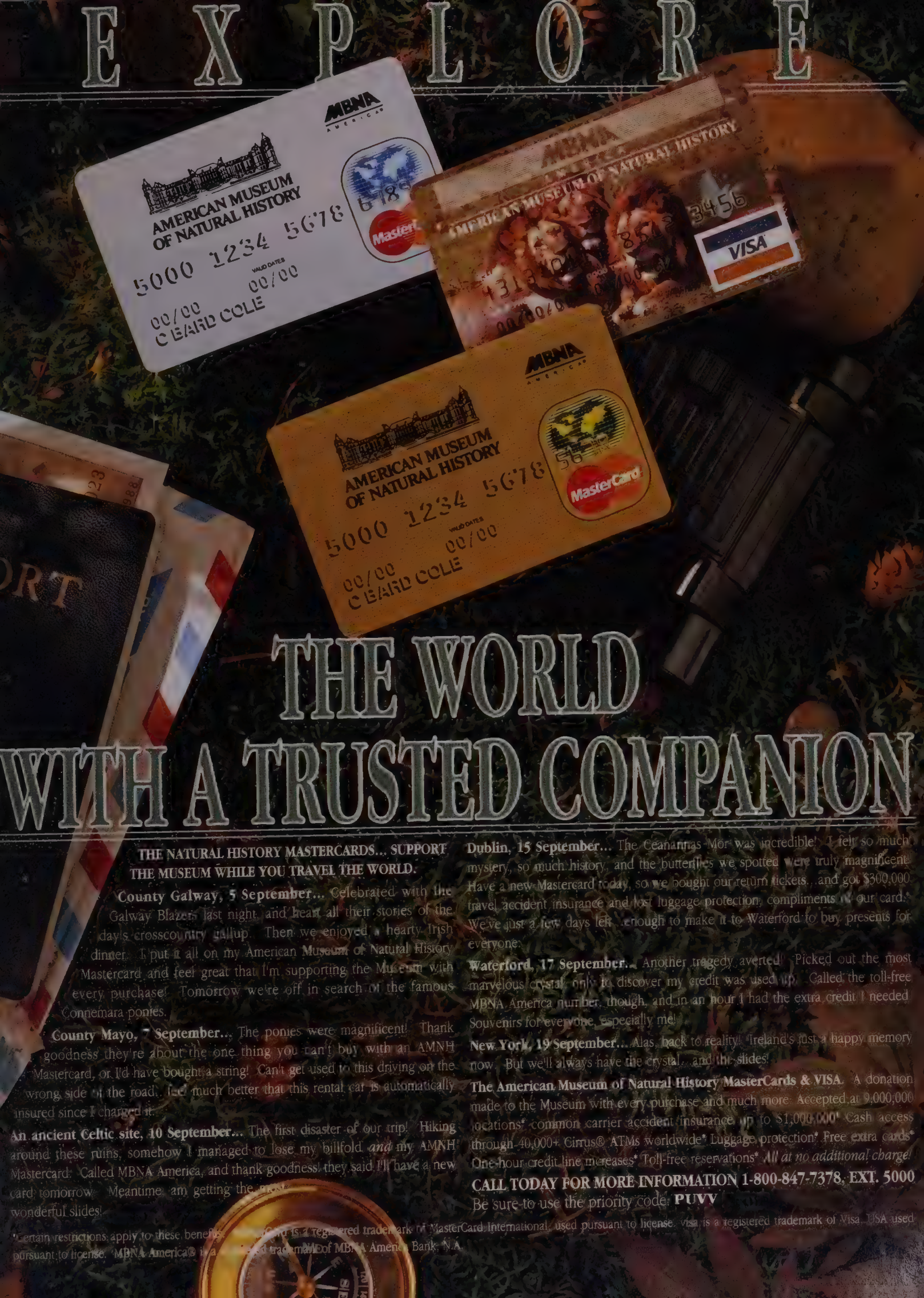
. . . What is needed is recognition of the reality that in so many fields, and this is particularly true of environmental issues, it is simply not feasible for sovereignty to be exercised unilaterally by individual nation-states, however powerful. Global environmental and economic security require global cooperation. . . .

The Rio Conference offers a unique opportunity to provide the basis for the major shift required to put us on the pathway to a more secure and sustainable future. At the core of this shift there will have to be fundamental changes in our economic life—a more careful and more caring use of the earth's resources and greater cooperation and equity in sharing the benefits as well as the risks of our technological civilization. Of particular importance is the need to integrate the ecological dimension into education and economics. . . .

. . . The world community now faces together greater risks to our common security through our impacts on the environment than from traditional military conflicts with one another. We must now forge a new "Earth Ethic" which will inspire all peoples and nations to join in a new global partnership of North, South, East, and West. . . .

. . . The people of our planet, especially our youth and the generations which follow them, will hold us accountable for what we do or fail to do at the Earth Summit in Rio. Earth is the only home we have; its fate is literally "in our hands."

—Maurice F. Strong
Secretary General
United Nations Conference on Environment and Development



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County Mayo, 7 September... The ponies were magnificent! Thank goodness they're about the one thing you can't buy with an AMNH Mastercard, or I'd have bought a string! Can't get used to this driving on the wrong side of the road, but much better that this rental car is automatically insured since I charged it.

An ancient Celtic site, 10 September... The first disaster of our trip! Hiking around these ruins, somehow I managed to lose my billfold *and* my AMNH Mastercard. Called MBNA America, and thank goodness! they said I'll have a new card tomorrow. Meantime, am getting the most wonderful slides!

Dublin, 15 September... The Ceanannas Mor was incredible! I felt so much mystery, so much history, and the butterflies we spotted were truly magnificent. Have a new Mastercard today, so we bought our return tickets, and got $300,000 travel accident insurance and lost luggage protection, compliments of our card. We've just a few days left, enough to make it to Waterford to buy presents for everyone.

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New York, 19 September... Alas, back to reality! Ireland's just a happy memory now. But we'll always have the crystal, and the slides!

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Multiple Occupancy

In the Georgia sandhills, development threatens the gopher tortoise's status as burrow landlord

by Russell L. Burke

One warm spring day I was in a longleaf pine and turkey oak forest in the sandhills of southern Georgia, trying to count gopher tortoises. With its widely spaced trees, low ground vegetation, singing birds, and scarcity of bothersome insects, it was a very agreeable place to be. But because this secretive tortoise spends 90 percent of its time hidden underground, censusing was difficult.

Evidence of these burrowing reptiles was everywhere, especially along an abandoned dirt road that wandered through the gently rolling hills. Numerous sandy aprons marked the mouths of their burrows, and trails through the wire grass showed where these terrestrial vegetarians came up to feed. But even after ten months of work here, I had yet to see a single tortoise.

Tortoises in general are of tropical origin, and North America's tortoise genus *Gopherus* evolved some 25 million years ago under relatively warm conditions on what is now known as the Great Plains. As climatic conditions cooled, many species became extinct, but fossil evidence shows that the four surviving American tortoise species in the genus gradually shifted their ranges south and developed burrowing abilities.

Of the four, the gopher tortoise is best adapted to burrowing. Its wide, short nose and skull, sturdy, muscular neck, and elephantine hind legs are modified to brace

A concealed camera catches a tortoise entering its burrow.
Fiona Sunquist

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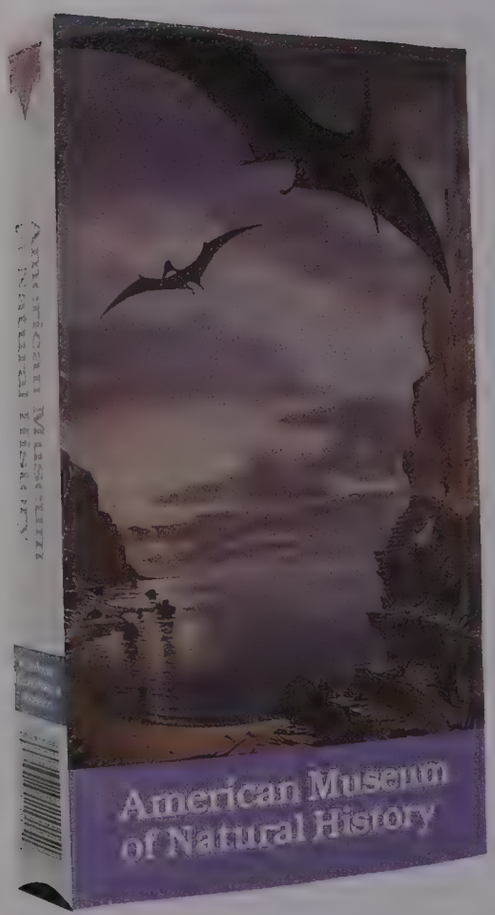

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the animal as it digs with its powerful, spadelike forelimbs. Gopher tortoises are unusually tolerant of the high carbon dioxide levels in their burrows, the result of decomposing fecal matter and poor ventilation. In addition, the humid conditions within burrows protect the tortoises from dehydration.

With its ten- to twelve-inch, mostly tan or brownish black shell, a gopher tortoise should stand out well against the vegetation. Although it feeds during the day, it can go without food for weeks between trips above ground. It is extremely sensitive to ground vibrations and can detect a human footfall from a considerable distance (relative to its head size, the vibration-sensing structures of its inner ears are among the largest of any vertebrate).

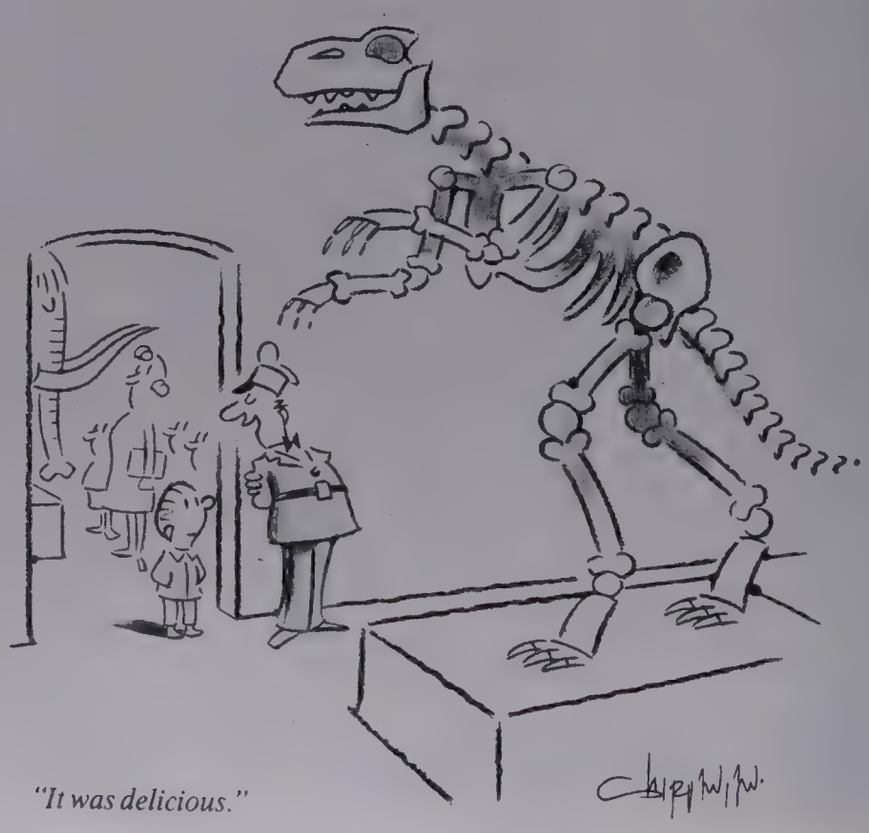
The burrows are easy enough to spot, but not all of them are inhabited. During its long lifetime—perhaps more than sixty years—a single tortoise may dig and maintain a large number of homes. With its forelimbs, it can shovel out thirty-foot-long burrows (the record length is forty-seven and a half feet) that may be more than fifteen feet deep. The tortoise prefers a tunnel not much wider than necessary for its passage, but as it grows it needs a larger burrow. Rather than simply enlarging the first, it often digs another or makes use of a previously excavated one.

Tortoises may shift burrows seasonally to follow food crops as they become available. Females often nest in the sandy apron of a burrow that is exposed to sunlight and may choose to move to such a site just before egg-laying time. And males maintain a number of burrows for short-term use as they wander in search of mates. Because the number of burrows in any given area is a poor index of how many tortoises are occupying them, I needed a quick, reliable way of determining how many there actually were.

One of the time-honored ways of censusing tortoises is to dig out the burrows. On a trip to Florida in 1917, Theodore Roosevelt, then president of the American Museum of Natural History, did just that. "The burrow was shallow and we speedily dug out the occupant," he reported. "It was a fairly large specimen, weighing 11½ pounds, with a shell 13½ inches long, 9 inches wide, and 5¼ inches deep. The gopher tortoise is a vegetable feeder and its flesh is good eating."

Roosevelt was lucky. I've tried to excavate burrows using shovels and backhoes; both methods are extremely labor-intensive. Burrows bend and dip in response to roots and rocks and tend to gradually curve to the right, even in the absence of any obstructions. Nearly the entire burrow must be excavated in order to find the tortoise, resulting in an enormous hole. "When my excavation was completed," remarked one biologist early in the century, "so large a pit had been dug that a coach and a span of horses might have been swallowed up in it."

My censusing project took place in a small, old-growth forest known as the Wade Tract Preserve. Before modern forestry, agriculture, and the development



"It was delicious."

boom, this type of longleaf pine and turkey oak forest dominated the southeastern United States and was home to millions of tortoises. The 200-acre preserve presented a unique opportunity to study the species in its ancestral home.

After I had spent several days searching unsuccessfully for a single tortoise, my brother and father finally convinced me that using their electrical, mechanical, and optical skills, they could make a remote-control carrier that would carry a video camera down into the burrows. After several prototypes, a 9-by-6-inch miniature "tank"—carrying a tiny video camera and a motor to push its treads—emerged. Powered by a small motorcycle battery, the entire apparatus fit easily into my knapsack. I could now sit at the burrow mouth, operate the controls, and follow the progress of the "burrow bug" on my portable monitor. (My previous experience playing video games proved useful, perhaps for the only time in my life.)

When I sent the burrow bug down a burrow for the first time, I realized that except for the camera's lights, I was seeing the burrow much as a tortoise does. The hard-packed floor sloped away into darkness, while the walls and domed roof seemed alive with "gopher" crickets, waving their long, sensitive antennae and fleeing from this strange intruder.

I steered around several turns, past broken roots and mysterious side passages (perhaps dug by other burrow inhabitants, but too small for the burrow bug). After a journey of a couple of minutes, I reached the end. Because of the camera's limited depth of field, I was not sure at first of what I was seeing. But after a little controlled jiggling of the burrow bug, I realized that I was viewing the rear end of a shy tortoise.

Over the next few weeks, I examined the interior of numerous other burrows, finding about thirty tortoises. In most cases, they were in the enlarged chamber at the bottom. Once, however, I encountered a tortoise about six feet down. Facing the camera, it stood its ground for about five seconds, bobbing its head vigorously as tortoises often do when encountering other tortoises, and then whipped around and headed for the bottom of the burrow. (If I made the burrow bug more tortoiselike, I wondered, would I have a shoving match with a territorial tortoise?)

On these visits, I had only a tantalizing glimpse of some of the many organisms that share a gopher tortoise's burrow. More than sixty vertebrate species use the burrows, from tiny toads and lizards to alligators and bobcats. Seven birds—bobwhites, wild turkeys, burrowing owls, Car-

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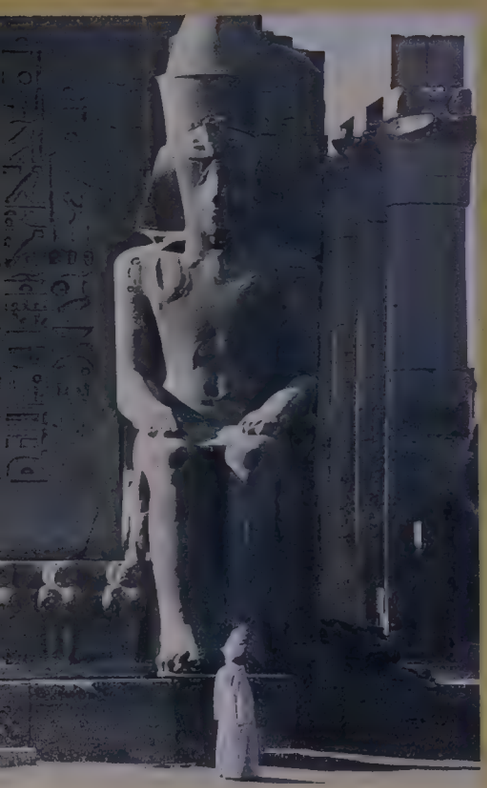

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olina wrens, American robins, Bachman's sparrows, and rufous-sided towhees—use burrows as shelters from predators and as hunting grounds for invertebrates. Of the latter, 302 species, including land snails, crayfish, arachnids, centipedes, millipedes, and insects, have been documented in tortoise burrows.

Outside the burrows, gopher tortoises feed on pine needles, herbs, various grasses, fallen tree leaves, fruits, berries, insects, mushrooms, and seeds. Because tortoises often defecate outside their burrows, the seeds from their meals are left in packets of fertilizer along their feeding trails. I've seen grasses, cactuses, and numerous other plants sprouting from the tortoises' feces, showing their importance as seed dispersers.

The trails converge at a burrow mouth. While most of the sand from the burrow is merely packed against the tunnel walls, enough is pushed outside to make a sandy apron about one yard square. Often the only exposed soil in the forest, the apron is an excellent location for the tortoise to bask and lay its single clutch of three to twelve golf-ball-sized eggs each year (usually in May and June, beginning when a female reaches ten years of age). The apron's edges are colonized by annual plant species rarely found elsewhere in the forest, and here the absence of highly flammable undergrowth and litter protects seeds and seedlings from fire. Even long-abandoned burrows support a much greater diversity of plants than surrounding areas do.

Squat, stout gopher frogs can be seen poised at the mouths of burrows, perhaps waiting to snag insects coming to investigate the cool darkness. The frogs do no digging themselves but readily dive into the burrows for shelter if danger threatens. They prefer inhabited burrows, perhaps because flies, beetles, crickets, and moths are attracted to cool, damp darkness and tortoise feces. At the beginning of the breeding season, gopher frogs leave their borrowed homes to congregate at breeding ponds. Afterward, many return to the same burrows in which they metamorphosed two to three months before.

In the more southern parts of the gopher tortoise's range, the Florida mouse may be found a little farther down the burrow. This largish mouse, recognizable by its hairless ears, digs two types of extra tunnels. One is a roughly vertical "chimney," which may serve as an alternative entrance or exit to the main burrow. The other is a narrow side tunnel that circles back around to the main tortoise tunnel, providing the mouse with another backdoor for emergency exits. These side tunnels also include an enlarged chamber where the female raises her young. Florida mice readily utilize burrows that are not in use by tortoises. From this base of operations, the mice emerge at night to forage in the surrounding vegetation.

Probably one reason that the mice are so concerned about escape routes is that the burrows are also regular haunts of indigo snakes, pine snakes, black racers, and diamondback rattlesnakes. Snakes use burrows for hibernation and shelter, and possibly as feeding grounds. Occa-

"Let there be cuckoos, a lark, and a dove.
But most of all, Miss Prescott, let there be grosbeaks."

sionally, snakes will eat a young tortoise.

For the gopher tortoise, the long tunnel provides a precise thermoregulation device. Temperature, humidity, oxygen, and carbon dioxide levels change gradually as the burrow descends but are remarkably constant at a given depth. Biologists at the University of Florida monitored tortoise movements and burrow conditions and discovered that a tortoise will move frequently within the tunnel in order to maintain a relatively constant body temperature. At the start of a winter cold snap, for example, the tortoise stays in the bottom chamber, where temperatures are highest. As cold air seeps down, the tortoise moves up with the remaining warm air until it is near the burrow mouth. In spring, tortoises are often found near burrow entrances, taking advantage of the sunny weather to warm themselves.

To further stabilize body temperature, a gopher tortoise's large urinary bladder is located against the rear of its shell. The bladder acts like a built-in hot-water bottle. It is easily warmed up while the turtle basks in the sun with its head facing down the burrow, ready to make a quick dash for safety if danger threatens.

At the bottom of the burrow is a somewhat enlarged chamber with a layer of fairly dry tortoise feces several inches thick. This mat is well drained, somewhat sweet smelling, and slightly damp. It forms the basis for a little-known fungus and animal community similar to that of a cave, but including numerous invertebrate species found only in gopher tortoise burrows. Many of these organisms are called commensals because they do not appear to benefit or harm the tortoise. Some, however, depend on the burrow for their very survival: if the gopher tortoise became extinct, these creatures would be lost. In other cases, the tortoise and the cohabitants may mutually benefit from their association.

At least twenty-one species of coprophagous, or feces-eating, insects (scarab beetles and specialized flies) have been found inside the burrows, as well as twelve kinds of predacious insects that eat them (robber and stiletto flies). Gopher frogs and other burrow dwellers probably eat these beetles and flies too. Thus, the plant material and moisture the tortoise brings in from outside nourish an entire community on several levels of the food chain.

While most commensal species appear to have little impact on the landlord, the coprophagous insects may benefit the tortoise. Although the interaction is not fully understood, these detrivorous insects may keep at bay parasitizing flesh flies that burrow into the tortoise's tissue.

Besides providing special conditions for a variety of long-term inhabitants, burrows provide a vital shelter for temporary visitors at critical times, especially during fires, which are a frequent natural event in the southeast. Most plants sacrifice some tissue and survive with relatively minor damage, while animals usually hide and try to escape the fire altogether. Many animals readily use the burrows for refuge. On separate occasions, I've seen a six-lined race runner lizard and a cottontail rabbit dash at least forty feet toward an approaching fire, then disappear into the safety of a gopher tortoise burrow.

A young gopher tortoise may utilize a nearby adult's burrow for a short time after hatching, but it soon starts digging its own home, sometimes enlarging an abandoned rodent burrow. These smaller burrows of young tortoises are often invaded by juveniles of the same commensal species that use larger burrows as adults. Eventually, the tortoise outgrows its burrow and moves on, often reopening and enlarging another abandoned one. Some burrows are used for decades, if not by tortoises, then by foxes, skunks, bobcats, or weasels as shelters and denning sites.

Unfortunately, the rapidly growing human population in the southeast also craves the upland habitats preferred by gopher tortoises. While phosphate mining, human predation (others besides Theodore Roosevelt have enjoyed tortoise meat), adverse forestry practices, rattlesnake roundups, and agriculture have taken their toll, urban development is currently threatening the remaining gopher tortoises. (Over the last hundred years, the tortoise population is estimated to have been reduced by 80 percent.) In Louisiana, Mississippi, and western Alabama, the gopher tortoise is currently protected under the Endangered Species Act and various state laws, but the laws don't extend to all the commensal species associated with the burrow community.

Recently, efforts have been made to remove tortoises from areas being developed and establish them elsewhere. But so far no one has succeeded in relocating the rest of the burrow community. Perhaps money should be spent to protect existing habitat, leaving the complex community around a gopher tortoise intact. This animal lives a very long time. Certainly, its health and the survival of its commensals depend upon the health of the sandhill habitat. And a tortoise burrow without its tenants is an empty house indeed.

Russell L. Burke is an evolutionary ecologist in the University of Michigan's biology department and museum of ecology.

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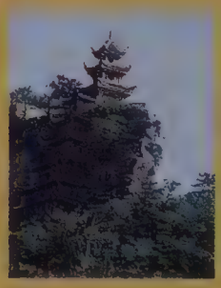

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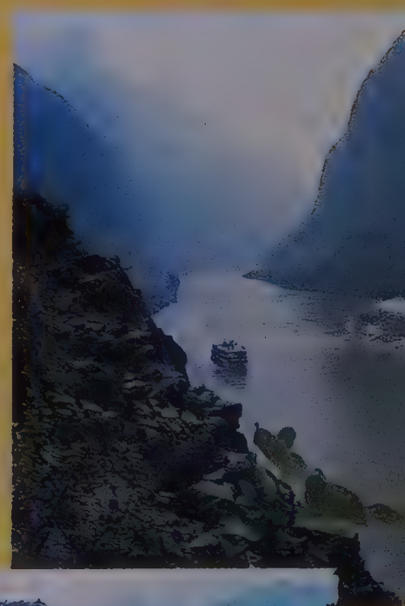

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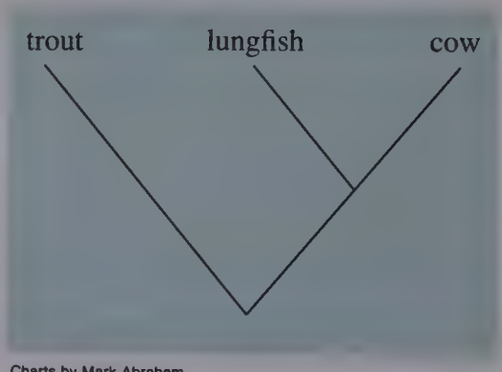
We Are All Monkeys' Uncles

If kings are to hermits as we are to chimps and gorillas, was Darwin wrong?

by Stephen Jay Gould

We learn from our errors, perhaps most of all from our shameful mistakes. I therefore begin with a story at my own expense. Many years ago, one of my students told me about her father's brother, a severely retarded man of childlike disposition. When she described him as "my uncle," I did a mental double take (and fortunately said nothing, so the shame of my error remained internal until now). I said to myself: "Uncles are wise people who render free advice (not always worthwhile) and take you to baseball games; how can a person with such limits be an uncle?" I then kicked myself (also metaphorically) and continued the soliloquy: "He is her father's brother; he is therefore her uncle pure and simple; uncle is a genealogical term of relationship, not a functional concept of action; he is as good and as true an uncle as any man who ever lived."

Evolutionary relationships are also genealogical, not primarily functional. We all understand that whales are mammals by history of common descent, not fishes because they swim in the ocean. In genealogical terms, closeness is defined by position in a sequence of branchings—what Darwin called propinquity, or relative nearness. I may look and act more like my cousin Bob than my brother Bill, but Bill is still closer to me by genealogy. Function and appearance need not correlate strongly with genealogical propinquity. To cite a classic example used before in these columns: all evolutionists agree that genealogical relationships among trout, lungfishes, and cows are correctly described in the accompanying diagram. Terrestrial vertebrates branched off the line of early fishes at a point near the ancestors of modern lungfishes; trout



Charts by Mark Abraham

evolved much later from a persisting earlier line of fishes. Therefore, if we choose to classify purely by genealogy, lungfishes and cows must be placed together in a group separate from trout. Many of us rebel against such an idea because our conventional classifications mix functional and strictly genealogical relationships. We may say that a lungfish looks like a fish, swims like a fish, acts like a fish and (presumably, for I have never had the pleasure) tastes like a fish. Therefore, it is a fish. Well, perhaps so; but by propinquity, lungfishes are closer to cows.

I don't wish to pursue this theoretical point in classification any further in this essay—although aficionados should note that this is the issue now engulfing the science of systematics in the debate about "cladism." Cladists advocate classification by pure genealogy (branching order), with no attention whatsoever to traditional concepts of similarity in function or biological role. For this essay, we need only carry away the lesson that genealogical and functional similarities are different concepts, and that we can be terribly fooled when we make a mistaken equation—particularly when we assume a closeness in branching (propinquity) from evidence of common appearance or behavior.

(Sorry, but I must add one more didactic paragraph: if we call a whale a fish, we make a simple error by misunderstanding the evolutionary phenomenon of "convergence." The fishlike characters of whales evolved separately and independently in a line derived from fully terrestrial vertebrates. But the fishy similarities of trout and lungfishes are genuine evolutionary marks of common ancestry. These similarities don't forge a closer genealogical bond between lungfish and trout than between lungfish and cow because such shared features are common characters of all early vertebrates; propinquity is marked by shared characters of later derivation. I would not, for example, use the character "five fingers" to unite humans and dogs, while placing seals in another group—for dogs and seals are genealogically close as members of the order Carnivora. Five fingers is a shared character of all ancestral mammals; it cannot help us make divisions *within* later mammalian evolution.)

If you have found the foregoing lesson abstract and dull, let me now reward your patience with a wonderful story (that becomes even better when you absorb the lesson). In functional terms, we would acknowledge maximal disparity between a king in his castle and a hermit in a hovel. But, as I argued above, functional and genealogical similarities need not be strongly correlated. Our legends are replete with scenarios of rags to riches: paupers become kings and frogs turn into princes. All the world's opulence does not debar the possibility that a king's closest cousin might be the meanest hermit in the land.

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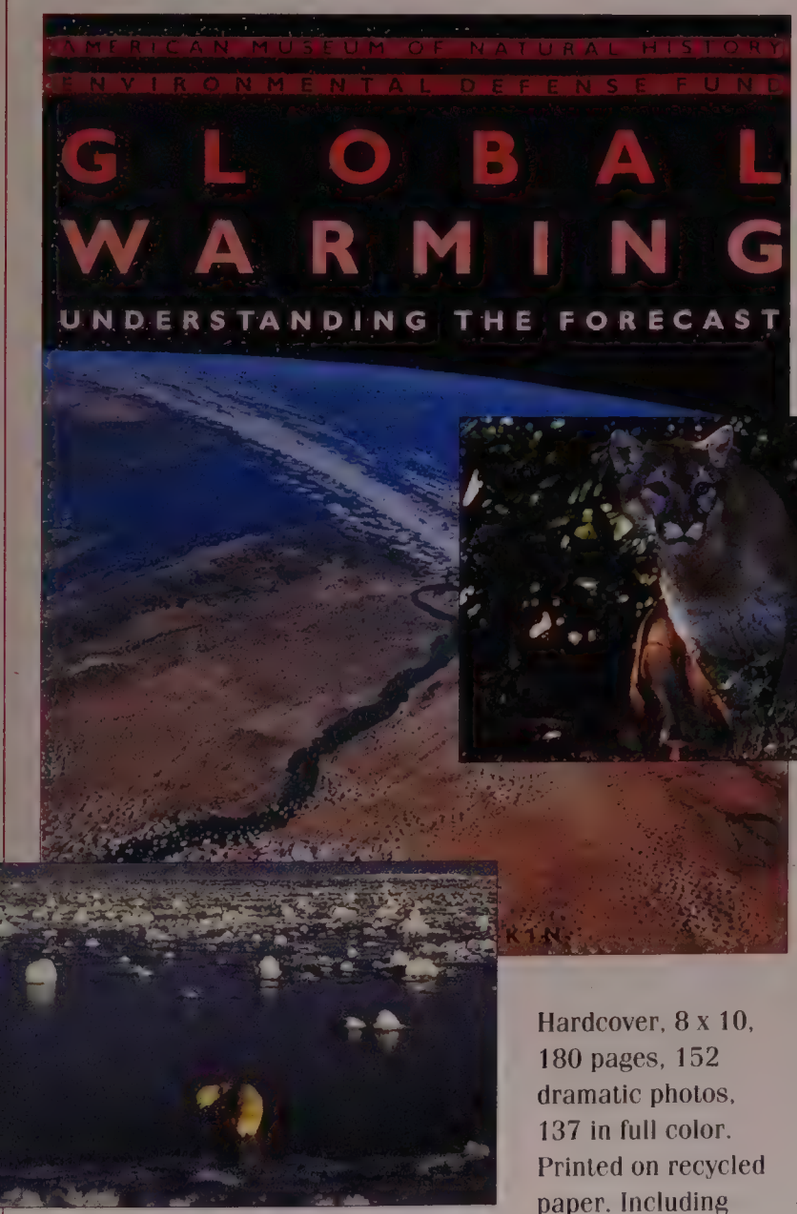

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Let us now contrast the kings and hermits, explicitly so called, of the world of crabs. We could scarcely find two more apparently different creatures in this admittedly limited domain. The king crab (*Paralithodes camtschatica*), a paragon

A king crab, greatly reduced
Nature, vol. 355, 1992, p. 540

of size within the brotherhood, lives in arctic and north temperate waters from the northern tip of Vancouver Island, all around Alaska, over to Siberia, and down the eastern Pacific margin as far as Japan. To borrow my earlier formulation for lungfishes, it looks like a crab, moves like a crab, acts like a crab, and certainly tastes like a crab—the basis for a prosperous Alaskan "fishery" (the correct English word, if taxonomically inaccurate in this case), which, at its height in the early 1960s, yielded 180 million pounds per year and a revenue equal to 40 percent of what the lucrative salmon trade provided. (Severe recent declines may be due to parasitism, disease, or overfishing—there we go again, with our chauvinistic vertebrate-centered etymologies.) The largest individual ever captured had a leg spread of just under five feet and weighed 24.5 pounds. Ten pounders with a three-foot leg span are common in the trade.

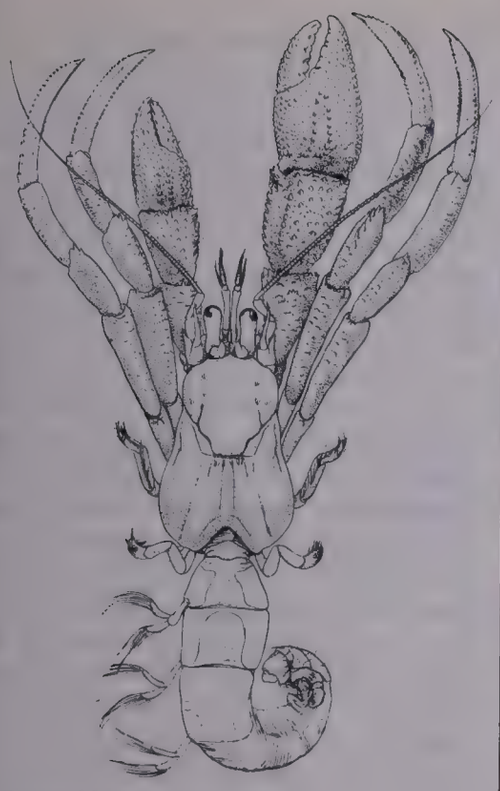
By contrast, consider the humble hermit crab—actually a large group of related forms, including some 800 species in more than 80 genera. Most are an inch or two in length and live curled up inside an empty snail shell (which they eventually outgrow and "trade in" for a larger model). However great the difference in size and habits, the disparity in form between king crabs and typical hermit crabs is even more pronounced. King crabs look like ordinary crabs: their carapace (outer shell) is flattened and widened, and they bear a pair of claws up front and three pairs of long sturdy legs behind (most crabs have four pairs behind the claws).

By contrast, I don't know why anyone ever decided to designate the hermits as crabs in the first place. Crabs form one of three major divisions—with lobsters and shrimps as the others—within the large group of marine crustaceans called Decapoda. (The Arthropoda, biggest of all phyla, contains three great groups: the Crustacea; the Uniramia, including insects, millipedes, and centipedes; and the Chelicerata, including spiders, scorpions, and horseshoe crabs.) True crabs belong to the order Brachyura, meaning "short tail." As a defining feature, their abdomens (rear ends) are shortened and narrowed, tucked around the back of the body, and firmly pressed against the underside. (The flat and wide crab shell corresponds with the front part only of a lobster or a shrimp's body. The abdomen, source of good eating, extends out and back in shrimps and lobsters but disappears from sight—as a remnant tucked underneath the body—in crabs. Take the front end of a lobster, flatten it out, pull from both sides until the shell becomes wider than long, reduce the tail and tuck it under the body—and, *voilà,* you have a crab. The relationship among the three major decapod groups becomes clearer with this thought experiment.)

So why call hermits crabs at all? They are not members of the Brachyura by genealogy but form a separate group, called Anomura, in a never-never land between conventional shrimps and other decapods. Their bodies are elongate, as in shrimps. They have only two strong pairs of legs behind the frontal pair of claws (the two highly reduced pairs farther behind function to hold the animal within its borrowed shell). Most importantly, the abdomen is not reduced or folded up under the body. Instead, it is strongly altered and well adapted for fitting into snail shells. Hermit crab abdomens are soft and decalcified, all the better to slip neatly into a shell. Moreover, the abdomen is coiled to one side, mimicking the shell that will serve as its abode. So why are these creatures called hermit crabs? I would have thought that hermit shrimps fit appearances better.

And yet, experts have suspected for a long time that king crabs are not true brachyurans either, and that these Alaskan giants (and other members of their family Lithodidae) are closest cousins of hermit crabs. But how could such propinquity in genealogy permit the development of such maximal disparity in form and function? And how, given this disparity, did anyone ever suspect propinquity in the first place? Three arguments have been presented, and they make a strong, if not entirely convincing, case.

1. The abdomen of adult king crabs, although diminished in size and folded under the body as in true crabs, is asymmetrical in form, recalling the rear end of hermit crabs. A few other features of



Typical hermit crab, with right-twisting abdomen
British Museum (Natural History) *Zoology*, vol. III, no. 3, 1916, p. 115

adult anatomy also suggest hermit crab origins. Decapoda, the crustacean group of crabs, lobsters, and shrimps, means ten-legged. In true crabs, a frontal pair of claws and four posterior pairs of legs make up the complement of ten. In hermit crabs, as stated above, only two pairs of strong legs follow the claws, with the final two pairs reduced to small protuberances that grasp the borrowed snail shell. In king crabs, the first pair of reduced legs is secondarily enlarged to form a third pair of strong legs behind the claws; but the second pair remains small and inconspicuously situated under the body.

2. These sporadic similarities in adult form would never have made a strong case by themselves. Confidence in this odd linkage of kings and hermits rose, however, with the discovery of profound and pervasive likenesses in the larval forms of the two groups. Adult animals are often so strongly specialized and differentiated that most signs of ancestry are hidden or obliterated. But early larvae or embryos often retain the ancestral mode of development, in part because the complex assembly of adult from egg leaves little flexibility for substantial modification and in part because larval environments often remain stable while adult habitats change. I like to call this common (but by no means invariable) observation of larval conservatism the *Sacculina* principle, to honor a famous parasite of crabs (as it happens) that looks like little more than a blob of formless reproductive tissue when adult in the host's body, but shows clear signs of its

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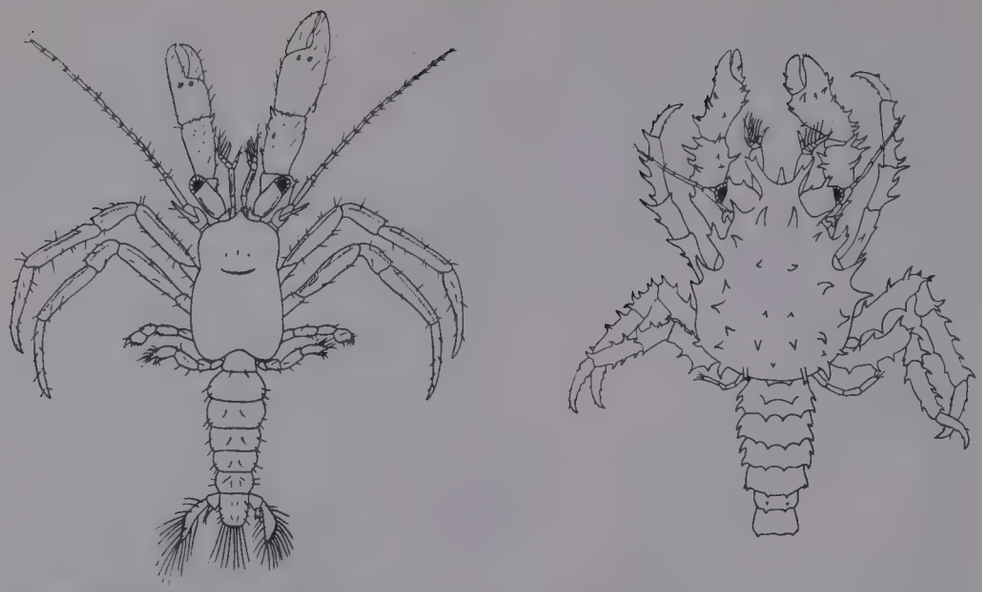


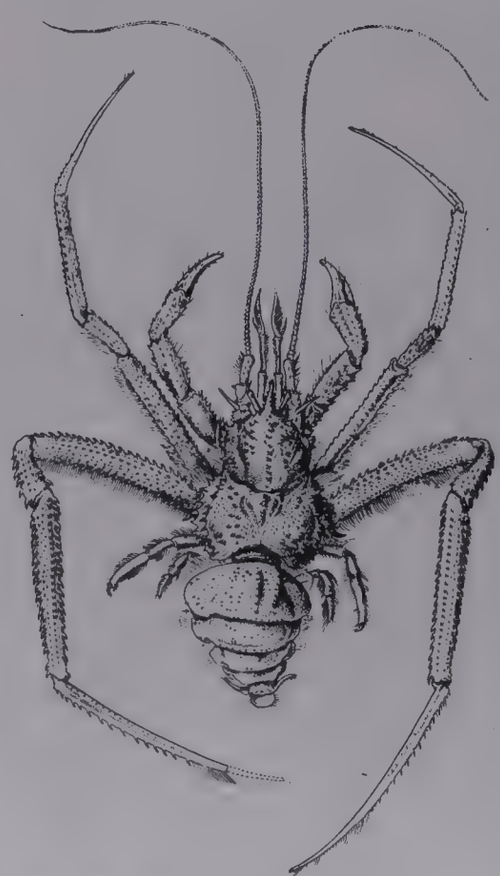
Glaucothoe (late stage) larvae of the hermit crab Pagurus bernhardus *(left) and king crab relative* Lithodes maia *(right)*
Proceedings of the Zoological Society of London, vol. 128, 1957, pp. 221 and 247

barnacle ancestry in free-living larval stages.

On the Confucian theme of equating a good picture with 10,000 words, the accompanying figure, from a crucial 1957 article that established the point, shows glaucothoe (late larval) stages of *Pagurus bernhardus,* a standard hermit crab, and *Lithodes maia,* a smaller relative of king crabs (*see* J. D. MacDonald, R. B. Pike, and D. I. Williamson, *Proceedings of the Zoological Society of London,* vol. 128, pp. 209–57). Some of the adult differences are already established (although the abdomens have yet to assume their asymmetry): the king crab cousin has already developed its characteristic spines and elongated the third pair of legs behind the claws. But the striking similarities of form now overwhelm the differences.

3. In the most fascinating and general point of all, convergent evolution to crablike form is an oft-repeated trend in decapod crustaceans. I will not speculate on either the advantages or ease of such a transformation, but merely record its multiple occurrences. Flatten the carapace, pull it out to the sides, suppress the abdomen and curl it under the body—and you have a crablike creature. So common is this trend that it even has a special name—carcinization ("crabification" in the less dignified vernacular)—conferred in 1916 by the celebrated British zoologist L. A. Borradaile. (Remember that we also call a cancer-producing substance a carcinogen, and that cancer itself comes from the Latin word for crab—a reference to the central mass and clawlike extensions of many tumors.)

Many evolutionary lines of hermit crabs have undergone carcinization. In some, the result is only partial—but halfway points give us especially valuable insights into the full process. Consider the accompanying picture of *Probeebei mirabilis,* a partly carcinized hermit crab properly classified in 1961 by the Danish zoologist Torben Wolff ("Description of a Remarkable Deep-sea Hermit Crab, with Notes on the Evolution of the Paguridea," *Galathea Report,* vol. 4, pp. 11–32). Note that the abdomen is still asymmetrical and twisted to the right, but it has become secondarily calcified. The two pairs of legs behind the claws are now strongly developed for free walking and extended to the sides, rather than protruding from the front (the proper position for sticking out from a snail shell). The basic reasons for such a change are probably not too far to seek in this case. *Probeebei* lives in deep waters off the coast of Costa Rica (Wolff's specimens came from a depth of more than 10,000 feet). Snail shells (and other potential homes) are rarely available at such depths.



Partly carcinized deep-sea hermit crab Probeebei mirabilis, *with less twisted and calcified abdomen and strong legs for free walking*
Galathea Report, vol. 4, 1961, p. 13

Two other cases hold special interest for understanding the transition and its frequent occurrence. *Porcellanopagurus,* the subject of Borradaile's original study, develops a shortened and fairly symmetrical abdomen. But this creature uses a clam shell, rather than a snail shell, for a cover—and you don't have to twist to fit under a basically flat plate. *Birgus latro,* the large and well-known "robber" or "coconut" crab of Pacific islands, shows us much of the process in its own growth. The adult is fully terrestrial and crablike in appearance, but juveniles still have twisted abdomens and inhabit snail shells at the shoreline.

We may move from these partly carcinized lines to four cases of virtually complete assumption of crablike form. Most successful, of course, are the true crabs (brachyurans) themselves, with thousands of species and worldwide distribution. But three other lines of fully carcinized crustaceans arose from hermit crab ancestry—two groups little known to nonspecialists (the families Lomisidae and Porcellanidae, the porcelain crabs), and the family Lithodidae, including the king crab (and fifty-two other species in sixteen genera—mostly much smaller animals and denizens of cold waters).

If doubts of the close propinquity between hermit crabs and king crabs persisted, they were recently dispelled, and convincing new proof provided, in an elegant study just published in the February 6, 1992, issue of *Nature,* the inspiration for this essay ("Evolution of King Crabs from Hermit Crab Ancestors," by C. W. Cunningham, N. W. Blackstone, and L. W. Buss).

This study, done in the laboratory of my friend and colleague Leo Buss of Yale University, takes advantage of the revolution in taxonomy now under way thanks to recent technological advances that allow us to sequence DNA cheaply and rapidly. Conventional taxonomy struggles with fewer morphological, physiological, and behavioral traits often frustratingly subject to convergence. Sequencing of DNA and RNA provides hundreds or thousands of newly available characters (the ordering of strings of nucleotides, often highly

conserved in evolution). These are, of course, equally subject to convergence and other forms of confabulation, but what a bounty of novel evidence!

Buss and colleagues sequenced part of an important gene that codes for ribosomal RNA, and they found 108 "phylogenetically informative" positions—an enormous increase in the number of useful characters for classification. They developed a matrix of similarities for all pairs of comparisons among twelve species of hermit and king crabs and a thirteenth more distant relative, chosen to anchor the tree (and called an outgroup in our jargon; they used the brine shrimp *Artemia salina*). They then applied a variety of standard tree-building techniques to this matrix of relative similarities. They achieved the same basic result with either of the two most common methods for tree building—distance analysis, which works only with measured degrees of overall similarity; and parsimony, which constructs trees with the minimal number of evolutionary steps. The invariant result from different procedures greatly increases our confidence in their findings.

Their remarkable and enormously satisfying result is shown in the accompanying diagram, reproduced directly from their article. *Artemia* is, as expected, separated from the twelve other species at the oldest division. The next dichotomy (A on their diagram) follows traditional classification by dividing hermit crabs with large left claws (the two lower species) from their cousins with large right claws. The large upper clump of ten species represents ordinary, traditional hermit crabs of the family Paguridae. The next division (B on their diagram) makes a basically geographic separation within the Paguridae.

We now come to the truly remarkable point: Notice the two lower species in the

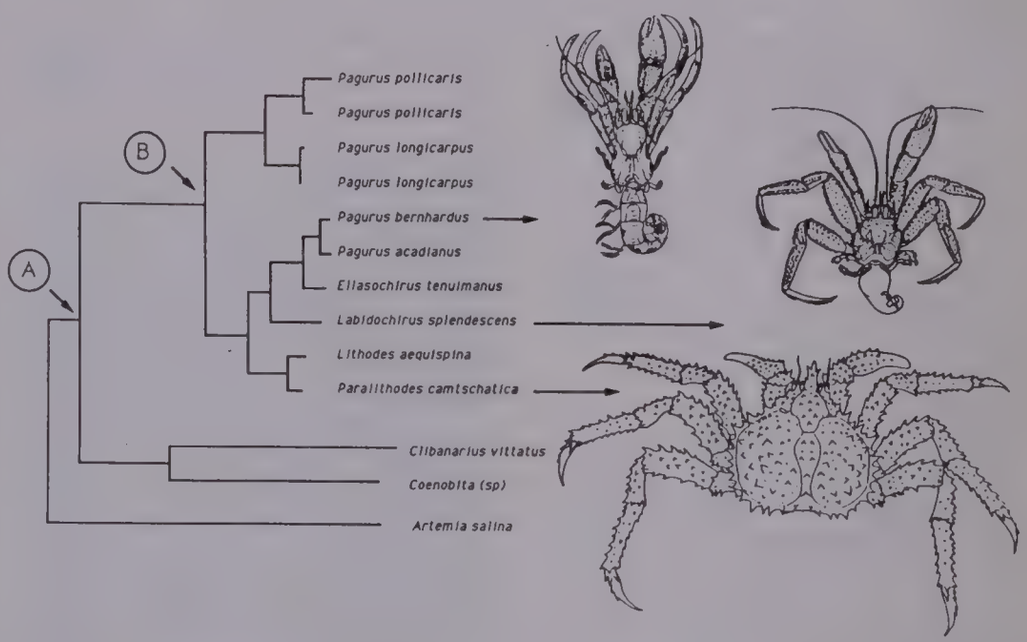


Diagram of genealogical relationships of hermit crabs and king crabs from a recent article by Cunningham, Blackstone, and Buss
Nature, vol. 355, 1992, p. 540

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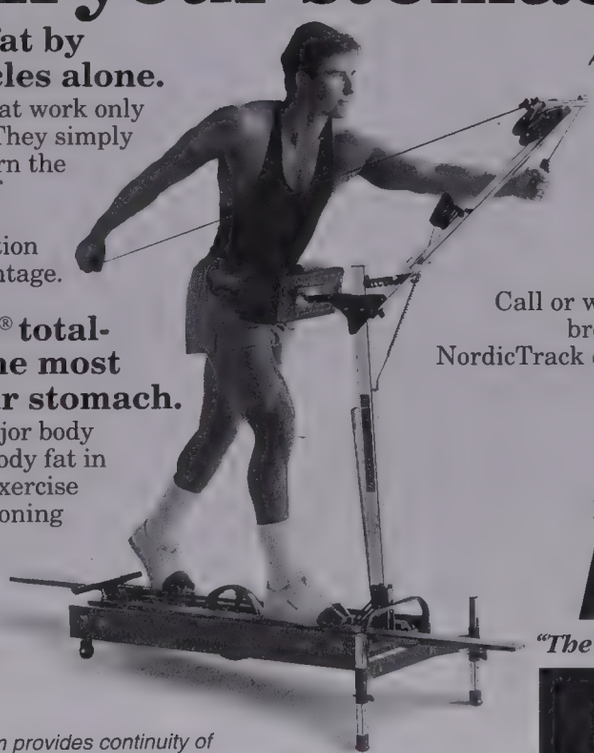

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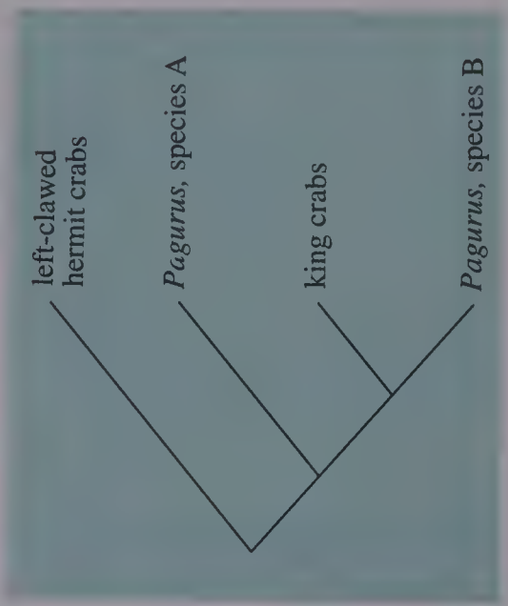
upper clump—the king crab (*Paralithodes camtschatica*) and its close relative *Lithodes aequispina*. Now consider the species in the two major subclumps of this larger group formed at the separation of right- and left-clawed lines at division A. The upper subclump represents species of the genus *Pagurus*, the standard hermit crab of any textbook or local seashore. But now look at the lower subclump—and note that it includes two further species of the genus *Pagurus*, along with the two species from the king crab line. In other words, king crabs are so close to hermit crabs by the proper criterion of propinquity that they actually branch off *from within* a narrowly restricted genealogical grouping so conventional in form and behavior that they have all been included in the canonical genus *Pagurus*.

The form of the tree also allows us to make a reasonable inference for the time when the king crab lineage split from conventional hermit crabs. Point A, the splitting of left- and right-clawed hermit crabs, can be estimated at some 73 to 78 million years from independent evidence of fossils. The geographic division of regions within right-clawed hermit crabs (point B) occurred some 35 to 40 million years ago, again by independent geological and paleontological evidence. By extrapolation downward, king crabs split from the genus *Pagurus* some 13 to 25 million years ago—a good stretch of time, but not a great deal (geologically speaking) for the evolutionary work accomplished.

One tangential point before leaving this elegant study. Critics of evolution often charge that the subject is untestable and therefore not properly scientific at all. This claim is rhetorical nonsense. How could you ask for a better test, based on a very risky prediction, than this. The counterintuitive link between king and hermit crabs was postulated on the basis of classical evidence from morphology (the arguments detailed in points 1 to 3 in this essay). This prediction was then tested by the entirely separate data set of DNA sequence comparisons—and confirmed in spades, with even closer propinquity than suspected between king crab and hermit crab lines.

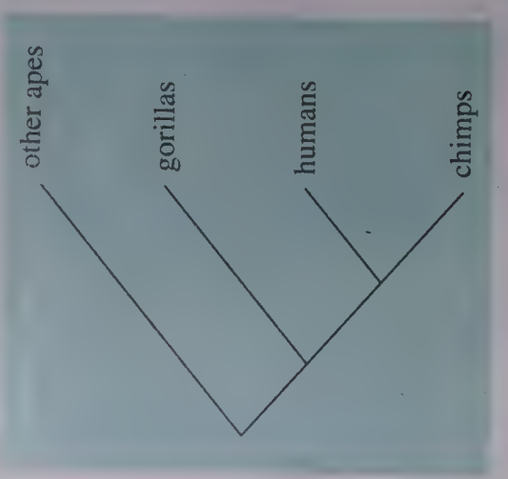
I regard this story of king and hermit crabs as one of the most elegant that I have learned of late in evolutionary biology—a lovely combination of a fascinating and counterintuitive tale; a multifaceted, rigorous, and convincing pile of supporting data; and a lesson of intriguing generality (the difference between genealogical propinquity and any functional meaning of similarity—and the overriding importance of propinquity). But can I bring you along with me in the face of an obvious demurral that many readers will offer: yes, I do grasp your story, but I'm not moved very much by crabs. They just don't intersect my life very often, so why should I care? Let me try to overcome this reticence by giving another example of precisely the same evolutionary phenomenon—one to which you simply cannot be indifferent.

The accompanying genealogical diagram epitomizes our surprising crab story. King crabs branch off from the hermit



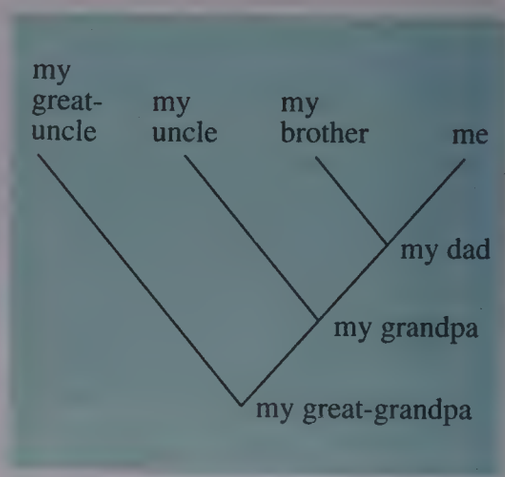
line within the space of the genus *Pagurus*, the most ordinary and conventional of all hermit crabs. Who would have thought that such a difference could be achieved in so little genealogical space? Who would have imagined that kings and hermits could be so close by the most important of all evolutionary criteria—propinquity, or genealogical distance?

I now reproduce the exact same diagram. I have made no changes whatever in the positions and orderings of branches. I have, however, substituted different names, for I now wish to diagram our best knowledge of propinquity in the so-called higher primates. Interestingly enough—for this was my second inspiration in deciding to write the essay—the genealogical story of how humans fit with closest primate relatives is exactly and formally the same as the tale of propinquity between king crabs and hermit crabs.



Darwin correctly surmised, and little doubt has been entertained by scientists ever since, that chimps and gorillas are our closest relatives. But Darwin, and nearly everyone else until recently, assumed that chimps and gorillas represented the closest genealogical pair among the three species—only reasonable after all, given the evident similarity between the two apes, and our obviously exalted separateness. (But remember that functional and genealogical similarity need not correspond.) All the evidence is not yet in, and the issue is still subject to wide debate, but most of the latest information suggests that we have been wrong—and that chimps and humans form the closest genealogical pair, with gorillas branching off a bit earlier.

Chimps and gorillas are conventionally classified in the family Pongidae, with humans in the separate family Hominidae. But if my diagram is correct, then humans arise *within* the space of the Pongidae and cannot therefore represent a separate family, lest we commit the genealogical absurdity of uniting two more distant forms (chimps and gorillas) in the same family and excluding a third creature (humans) more closely related to one of the two united forms. I surely cannot claim to be more closely related to my uncle than to my brother, but we make exactly such a statement when we argue that chimps are closer to gorillas than to humans—see the third diagram of identical topology.



Hermit crabs and king crabs tell exactly the same story. Our instincts inform us that the two groups should be separated in classification to recognize their profound differences in form and function. But king crabs arise genealogically within the space of hermit crabs—indeed within

the restricted space of the canonical genus *Pagurus*. So how can we place king crabs in one evolutionary group and hermit crabs in another? Similarly, how can we continue to rank humans in glorious separateness, while we unite chimps and gorillas in the family Pongidae?

We may legitimately inquire how such apparent differences could arise in such a restricted genealogical space. But perhaps we are fooled by appearances, and the underlying differences are not so great (or perhaps they are truly profound and evolutionary rates have been enormously accelerated in the king crab and human lines). Small underlying changes can yield large accumulated effects if introduced early in growth, with cascading consequences thereafter. Maybe carcinization is not so big a change after all—flatten and widen the carapace and reduce the abdomen. Maybe all this can occur as consequences of a single coordinated transformation in growth (as the authors of the *Nature* article suggest). After all, *Birgus latro,* as discussed previously, undergoes such a transformation in its own growth—as it lives with a twisted abdomen in a snail shell during its youth, but then carcinizes and becomes free living as an adult. Moreover, the large size of king crabs, however impressive, need not represent a major evolutionary change. Abandon the necessity of finding a shell for a house, and limits to size are abrogated. Any carcinized free-living hermit crab may possess the capacity for greatly expanded size.

Similarly for humans: are we really so different from chimps as we so confidently and arrogantly assert? In appearance, sure (reduced hair and erect posture have a strong visual impact). In brainpower, undoubtedly (chimps are smart as hell, but they will never ponder the genealogical position of king crabs). But the underlying biological differences need not be so great. Strengthen and straighten the legs, enlarge the brain. The consequences have been enormous and unprecedented in all the history of life, but I am not so sure that the topological and genetic transformations have been so profound. Consequences are effects, and effects are not the same thing as generating forces and morphological results. Small changes can have cataclysmic effects.

People of good will and intelligence readily acknowledge our kinship with apes and monkeys. We know it in our heads and can parrot the appropriate phrases. But we have never incorporated this vital knowledge deep within our guts. We have not been able to do so, in large part, because we have mistakenly assumed that functional and genealogical distances must be strongly correlated. If we look so unlike a chimpanzee, then we must really be very different, whatever our kinship. But if we ever properly grasp the primacy of genealogical distance as an evolutionary measure, and if we ever understand how illusory an outward appearance can be as an indicator of fundamental difference, then we might reassess to our enormous (if humbling) advantage. Kings can be hermits and humans can be closest brethren to chimps.

The motto of the functional view proclaims: *Der Mann ist was er isst* (you are what you eat). But an evolutionist must add the defining voice of history: you are what you have been and what your closest genealogical nexus shares. Think kinship. We will be a bit freer, a bit more enlightened, a bit readier to work for planetary preservation with the rest of kindred life, when we truly know why each and every last one of us is a monkey's uncle.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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Gaspésie Park, Québec

by Robert H. Mohlenbrock

Ranging 1,500 miles northward from Georgia, the Appalachian Mountains end in the Shickshock Mountains of Québec's Gaspé Peninsula. The peninsula is framed on the north by precipitous cliffs that tower above the Saint Lawrence River and on the south by gentler terrain that slopes into the Baie des Chaleurs. Numerous picturesque fishing villages nestle in the coves around the coast, but the mountainous interior is nearly uninhabited by humans. The highest peaks have been set aside as part of Gaspésie Park, a 310-square-mile preserve administered by the provincial government.

Gaspésie Park is home to some 250 woodland caribou, most of which live on the flattened summit of Mont Jacques Cartier, several hundred miles south of other populations of this species. (Logging, farming, and hunting have eliminated the animals from the intervening territory.) The park is the only area in North America where white-tailed deer, moose, and woodland caribou share a habitat. Black bears are found there as well.

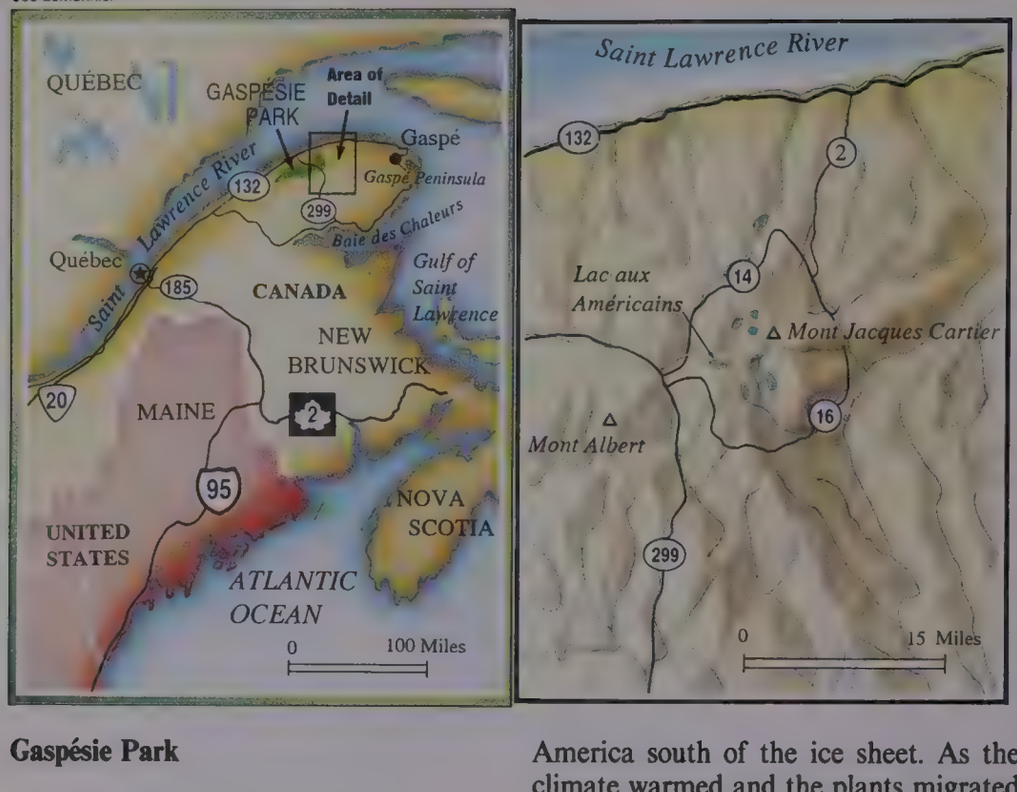
The Gaspésie also boasts an unusual combination of plants. In addition to boreal forest species, such as white spruce, black spruce, balsam fir, and dwarf birch, there are plants typical of the Arctic, about 1,400 miles farther north, and of the Rocky Mountains, 2,000 miles to the west. Some of this diversity can be traced to the effects of the last Ice Age, which reached its maximum some 80,000 years ago and ended about 12,000 years ago.

One of the first scientists to examine the impact of this glaciation on the Gaspé was

Jessie M. Harris

The treeless summit of Mont Jacques Cartier, left, is the highest point of the Shickshock Mountains, an extension of the Appalachians. Above: Caribou on Mont Albert.

Joe LeMonnier



Gaspésie Park

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geologist A. P. Coleman. Unable to find glacial drift on the mountains, he proposed in 1922 that the ice sheet from the north had missed the interior of the Gaspé Peninsula, with one lobe passing to the east and another to the west. Based on this suggestion, botanist Merritt L. Fernald speculated that at the height of the glaciation, the Shickshock mountaintops provided a refuge for arctic and Rocky Mountain plants. But in 1935, glacial drift and smooth boulders were discovered in the Shickshocks, showing that the entire range, including the summits, was probably once covered by ice. As a result, botanists now conclude that plants colonized the mountaintops after the ice had retreated to the north.

The arctic species, which presumably had been driven southward as the glaciers advanced, recolonized the mountaintops as conditions again became favorable. The presence of Rocky Mountain species is more difficult to explain. Some North American plant species appear all along an arc that curves from the Rocky Mountains northeast to the Arctic and then southeast to the Gaspé highlands, while others grow only at each end of this arc. Ecologist V. C. Wynne-Edwards has speculated that at the height of the glaciation, all these species ranged across North America south of the ice sheet. As the climate warmed and the plants migrated northward, the hardiest ones were able to colonize the Arctic, but the least hardy were able to survive only at the eastern and western ends of their distribution—in the Rocky Mountains and in the Shickshock Mountains.

Variation in the type of rock that forms the Shickshocks has promoted the development of several plant communities. The 4,160-foot summit of Mont Jacques Cartier is a tableland of pink and red granite with a rounded, treeless dome. Forests of spruce, fir, and birch cover the lower slopes of the mountain, but at about 2,900 feet, an entangled growth of stunted, intertwining spruces makes hiking extremely treacherous. Above this krummholz, or "crooked tree," zone is the open summit, called Botanist's Dome by early naturalists. Bordered by granite boulders of various sizes, it is home to arctic-alpine vegetation.

Over thousands of years, freezing and thawing have broken down the granite, creating an acidic soil supportive of plant life, including many members of the acid-loving heath family. On the summit of Mont Jacques Cartier grow Labrador tea, Lapland rosebay, alpine azalea, two kinds of mountain laurels, mountain heath, bog rosemary, leatherleaf, bearberry, bog bilberry, and rock cranberry. Most of these species have a circumpolar arctic distribution that extends north of the tree line from Labrador across Hudson Bay and the Northwest Territories and down through Alaska to the Seward Peninsula, as well as across the arctic regions of Europe and Asia.

In contrast, Lac aux Américains, nestled several hundred feet below the mountain summit, is partly bordered by lime stone cliffs, which have weathered to form a basic soil. The plants growing here, les than four miles from the summit of Mon Jacques Cartier, are "calciphiles." The include holly fern, two native fescu grasses, five sedges, two rushes, false as phodel, alpine rock cress, snowy cinque foil, and—growing mostly in small pock ets on the cliff face—four kinds o saxifrages. While some of these are cir

Lapland rosebay, a rhododendron, grows best in acidic soil.
Jessie M. Harris

umpolar arctic species, a number of hem are boreal, since they do not grow orth of the northern conifer forest.

The summit of Mont Albert, nearly 400 eet lower than Mont Jacques Cartier, is nderlain by serpentine rock that is home o an arctic-alpine flora peculiar to itself. Mont Albert has a rather flat top that is bout 3.5 miles long and 2.5 miles wide. Along the edge of the plateau on the north de is a dense krummholz of low-growing pruces. The branches of these dwarfed rees lie nearly prostrate; any upright ranches are usually killed by the drying ction of the high winds that frequently gust across the mountaintop. The rest of the plateau is treeless.

Serpentine rock, named for its undulating, layered texture, contains unusually large amounts of magnesium and iron. According to botanist Arthur Kruckeberg, serpentine soils are thin because they lack clay, and they are so inhospitable to plant growth that only certain highly adapted species can survive on them. Nonetheless, nearly two dozen species of plants are found on Mont Albert. Six—Christmas fern, wild oat grass, rough fescue grass, and three low-growing willows—grow in the Rocky Mountains as well, with few or no locations in between.

Although serpentine rock weathers to form a basic soil, several acid-loving species are found on Mont Albert, growing in raised bogs that are apparently little influenced by the rock beneath them. These plants include cloudberry, sheep laurel, small-leaved cranberry, leatherleaf, bog bilberry, and mountain honeysuckle.

This month, Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, has ventured beyond the U.S. national forests that make up his usual beat.

Bagging Game

Meet me where the lilac blooms

by Roger L. Welsch

Vito's instructions surprised me; I had expected intrigue, but his approach was straightforward: "Come to the house about ten in the morning Sunday. Park out in front of the house. Everyone in the neighborhood will be getting ready for church. I want 'em to see you. Knowing there is a stranger with me, they'll never suspect that I am making a 'run.' Wear clothes like we was going to the library. Don't bring anything that looks like a container. Don't carry anything in your hands or even your pockets. I want to look like we're going out to look at used cars or talk about life insurance."

During the long negotiations leading up to this moment early in spring, Vito had impressed me with his insistence on absolute secrecy. "I am sharing with you what a man shares only with his son," he said. "And just like you was my son, if you betray this confidence, I'll nail your gizzard on a fence post someplace west of Wahoo." I assured Vito that I understood the importance of secrecy, that I held sacred his confidence in me, and that being the kind of guy who is uneasy about getting a haircut, I was not likely to place my gizzard in jeopardy.

Just as Vito had told me, I arrived at precisely 10:00 A.M., parked in front of his modest home on Omaha's south side, walked boldly up to the front door, and knocked. Vito opened the door widely and invited me in. We had a cup of strong coffee while Vito reminded me again of his requirements: "My grandfather is probably spinning in his grave, what I'm doing today. Nothing you write or say to anyone better lead anyone to where we're going, not that you're going to know, once we get there, where we've been."

"What you just said," I nodded.

"Let's go."

We went out the side door to the tiny garage beside the house and crawled into his immaculate '57 Chevy. "I would have guessed we would take your old van for a job like this," I said.

"Nah. If I fired up that old beast, everyone in the neighborhood would know what I'm up to. Even over in the Slovak part of town, they know that van. I've gone past Pavelka's tavern in that van at straight-up noon, and by the time I went past the Sokol Hall at 12:05, there was already six Slovak cars sitting there waiting to follow me."

He started the Chevy, raced the engine a couple of times, and then sat in the driveway for a few minutes warming up the engine—and making it clear to his neighbors that we were in no hurry and were not trying to hide anything. Although of course we were.

As we drove through Omaha (I won't tell you what direction we took, mostly because I don't know what direction we took), every now and then Vito made a quick right or left turn and circled around a couple of blocks to see if we were being followed. After an hour or so of looping around the city and then snaking along gravel and finally dirt roads in the Missouri River bottoms, Vito pulled up his Chevy behind a decrepit corn bin.

"The farmer knows me," Vito explained. "For a share of the take, he lets me use the place. If someone's following me, he chases them off with a double-barreled ten-gauge. Here," he handed me a plain paper bag, a little smaller than the ones you get in a grocery store. "Put this in your back pocket. I don't want it out where it can be seen."

"But . . ."

"And don't talk out loud about what we're here for. The worst thing you can do is let your guard down now. We're not alone."

We walked through heavy woodlands for another quarter of an hour, stumbling down a ravine and across a couple of small creeks. Woodlands are not, strictly speaking, a usual part of the Nebraska landscape, except where we were, along the banks of the Missouri. We came to a small, level clearing—no, not really a clearing: there were still a lot of trees, but they were dead and so sunlight reached the forest floor and gave an impression of openness. Vito reached back with his left hand and without looking at me pushed against my chest, signaling me to stop and stay. He stepped slowly into the clearing. He patted his left back pocket, checking to see if the paper bag was still there. He stepped around a large, dead hackberry. I could see his face. What had been furrowed with intense, worried lines now opened up like this spot in the forest, full of light. Vito held both arms far out to his sides, his fingers open, the palms of his hands upward and open. He tilted his head to one side and laughed.

He circled the tree, squatted, and looked up. He stepped close to the tree and then well back from it. He motioned me forward. "Now you," he said. "Look at them from every angle. Squint. Open your eyes wide. Teach your eyes what it is they should be seeing. Look at the color and the texture. See how the light hits them. Look up close and far away." He held up his hand to cast a shadow on the tree trunk. "Look in shade and in light."

I stepped around the tree and looked at the bracket fungi known around Omaha as beefsteak mushrooms—huge, pink, fleshy.

"Don't pull out your sack until the last moment," Vito said. "The beefsteak knows. You'll scare away others."

Czechs, Germans, and even Omaha Indians had told me the same sort of thing about mushrooms: Mushrooms know. When you hunt mushrooms, you walk into the woods as if on a stroll, whistling a tune,

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enjoying the spring scenery, maybe even carrying a camera or fishing pole. No container should ever be carried in the open; mentioning the name of your quarry insures failure.

Woods and forests are not common on the Plains, so neither are mushrooms. I restrict my own searches to morels, inky caps and their relative the shaggymane, and when I am on the eastern fringes of the Plains, puffballs (known in Latin as *Calvatia gigantea,* but around here better described as *Calvatia punyea*).

Inky caps and shaggymanes are relatively easy to find (inky caps, for example, like elm stumps, and one of the reasons we don't have many trees these days in Nebraska is that we have increasing numbers of elm stumps). They are also relatively easy to identify, which has been an important factor to me since the day I read a detailed account of how one dies after ingesting the romantically named Destroying Angel. But these two abundant and delicious mushrooms, the inky cap and shaggymane, have the extraordinarily unpleasant side effect of making a lot of folks sick when either is combined in a meal with alcohol. If you're a Baptist, you'll love them.

Morel mushrooms are more elusive geographically than inky caps and shaggymanes but more seasonally restricted, sparing us the trouble of looking for them most of the year. I have heard a lot of folk theories about when one should seek the succulent morel, but traditional timing systems have their problems. Perhaps the most commonly mentioned sign for gathering morels, for example, is "when the leaves of an oak tree are the size of a squirrel's ear." But the time required to find an oak and catch a squirrel might be better spent looking for morels. "The last full weekend in April" is another unreliable guide, at least in Nebraska, where it can be 108° F in the shade the last full weekend in April or, alternatively, you might have to wear snowshoes.

Another traditional belief is that morels pop out when lilacs bloom. The Mr. Science in my life, Russ Meints, an old buddy who is a life-science wizard at Oregon State in Corvallis, explained to me that this belief probably arose because lilacs and morels operate on the same light schedule. So, when lilacs have had enough light to bloom, morels have had enough light to bloom too.

I suppose the real question about collecting mushrooms is, Why bother, when we can buy little wooden baskets of perfectly nice, safe mushrooms at the grocery store? But of course it's worth it! I even get a kick out of growing store-variety mushrooms from boxed kits I get by mail order from Pennsylvania.

ME: I grew these mushrooms myself, right here in the laundry room.

GUEST: Goodness, what a genius you must be!

ME: Oh, it's nothing, really.

The magic of morels and beefsteak mushrooms is even more powerful than that of button mushrooms grown under cover of my used socks. I grew up secure in the knowledge that no one could grow morels in captivity. If you want morels, you know where and when to look, you go out when the conditions are just right, you carry a paper sack in your back pocket, you don't say the word *morel* out loud, and you go get them. That sort of world makes sense to me. To the victor goes the prize, faint heart never won fair lady, and no morels without stumbling around in the woods all day on the right day.

Now, I understand, some French lunkhead has devoted his life to figuring out how to grow morels commercially, and if he has his way, ne'er-do-wells who don't even own a paper bag will soon be able to walk into the supermarket and say, "Why don't you give me a pound or so of those wrinkly tannish things over by the kiwi fruit?" I like to think that morels will never put up with that sort of nonsense.

You're thinking, this guy actually believes mushrooms see, hear, think, and scheme. Well, yes, I do, and I have plenty of evidence to support that understanding. Mushrooms even have a sense of humor.

I once took a class of college students out on the Platte River for a nature weekend—last weekend in April, lilacs blooming, oak leaves . . . well, you get the idea. Our intent was to gather morels and wild asparagus (which, around here, stabs toward the sky about the same time morels show up). Kim Pfeiffer, sister of my old pal Phil Pfeiffer, was in the front of my canoe, and as we skimmed along the riverbank, I tried to help her identify edible wild plants for a school project.

"That gray-green, fuzzy plant right there . . . there to your right . . . that's catnip. Lovely mint. Makes a nice tea. And that is a chokecherry bush; it will fruit about the first week or two of July."

But there were no morels, and we were on the river for morels. Kim had never seen a morel, so I tried to describe them: "They are sometimes called 'coral' mushrooms because they are wrinkled up like a brain, sort of, except they have pits rather than wrinkles, as opposed to false morels, which have wrinkles rather than pits. They are light tan, taller than they are wide, kind of pointy on the top, about the

"Tell Pa the gin is running."

size of my thumb." But we saw no morels.

Now, if you were a morel, what would you do to embarrass the wise-guy professor who is playing nature boy with a beautiful coed in a canoe? I know what you would do if you were a morel: you would hunker down under some leaves so the poor jerk would go home without having found one morel to show the young lady. Well, that's not what a morel would do.

We were floating along a small island somewhere between Grand Island and Central City when Kim asked over her shoulder, "Professor Welsch, is that a morel?" She pointed. I gasped. I fell over the back of the canoe. I struggled through the water toward the island. I stuttered. I drooled. There was a morel as big as my head.

"I thought you said morels are as big as your thumb," Kim said.

"Gagaboogada!" I sputtered, or something like that. I picked up this Mother of All Morels. It weighed pounds. This was a *Norman schwarzkopfea*. Later, when we butchered that morel, we found that although it was hollow, like all morels, it contained a second mushroom, so that the flesh was fully an inch thick. We halved it, then quartered the halves. Each eighth of that mushroom covered one huge T-bone steak.

I stood holding that mushroom until I regained some hint of composure and was about to say something like, "Kim, everything I told you about morels is true. This morel is a one in a trillion, mutant ninja mushroom." But before I could say a word, I saw another morel, just as big, a few steps away. And then another, and another, and another. Kim and I picked eight morels that day, so huge they were more than the two of us could carry back to the canoe in one trip. Morels have a sense of humor; no more were found that day. So Kim Pfeiffer, to this day, thinks (1) morels are about the size of a professor's head, and (2) both are hollow.

"Are you okay?" Vito asked, startling me.

"Yeah, I was just daydreaming about some other mushrooms I've known," I answered.

"Well, don't stand there too long. Take another look at this beefsteak and let's get going. I don't want to sit here any longer than I have to. Let's pick what we can and get out of here. There's been talk about some of the Slovak boys renting a helicopter."

Mushroom hunters are funny folks, all right. But then so are mushrooms.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

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When Is a Stick Not a Stick?

When it is a sexual partner for life

by John Sivinski

Insect copulations often have a certain vulnerable quality. Bodies ill designed to embrace appear awkward during mating. Courtship and copulation are sometimes very conspicuous, and almost always engrossing. Common sense suggests that nature would exact a price for awkwardness, as well as for inattention. To be obvious, oblivious, and shackled to each other would seem to be extremely dangerous. Anyone who has witnessed the disorganized flutterings of some mating butterflies can imagine the ease with which an observant blue jay could snatch a meal.

Given our perception of how perilous they are to the performers, we might expect insect pairings to be kept to a minimum, and indeed, for many species, sex is short-lived. In some wasps, the whole affair—from frenetic courtship to rapid ejaculation—spans less than a minute. The male cricket in one species passes his spermatophore (a capsule containing sperm) to his mate in under a second. Yet for a sizable minority of insects, mating i far from fleeting, and for a few, the awk ward postures and hobbled captivity o pairing are practically a way of life.

Among those that endure nearly indi visible union are certain species of stic insects. Also known as walking sticks phasmids, and specters, stick insects ofte closely resemble parts of plants. Thi mimicry frequently enables these herbivo rous, leaf-eating insects to escape detec tion by predators.

Many stick insects are little and spindly nd look very much like twigs. A few are onsiderably bigger, more like small ranches: at thirteen inches, the female of ne species from Borneo is among the ngest of all insects. Many species have dditional details mimicking their parcular environment. Green and thick as a nger, members of the genus *Hermarhus* have swollen ridges along their bodes that turn them into bamboo shoot lookkes. Numerous tropical forms bear warty excrescences, leafy flaps, and lichenous crusts on their abdomens and legs, enabling them to disappear into a background of foliage and mossy bark. One ten-inch giant of the Congo River basin carries a splintery, hornlike growth on its head that resembles the snapped-off stump of a smaller twig.

A few stick insects look like leaves. One species from Malaysia, for instance, is peculiarly expanded, flattened to a leafy thinness, and freckled with funguslike blemishes. Even the eggs of stick insects are sometimes not what they seem, often looking something like small seeds. On occasion, eggs closely match the seeds of the plants the insects frequent. One stick insect from the mountains of New Mexico glues its long, pointed eggs to grass stems, where they faithfully reproduce the appearance of the plant's own seeds.

A particularly graphic example of specialized plant mimicry is *Diapheromera covilleae,* a North American stick insect that lives solely on the creosote bushes of the southwestern deserts. The blotchy green-and-brown juveniles match the thin, fresh growth of their host. Even the bases of their legs take on the color and shape of the leaf petioles among which the insects graze. As the insect grows, the adult male puts on a light brown dead twig disguise, while the larger female imitates the purplish gray of larger creosote branches.

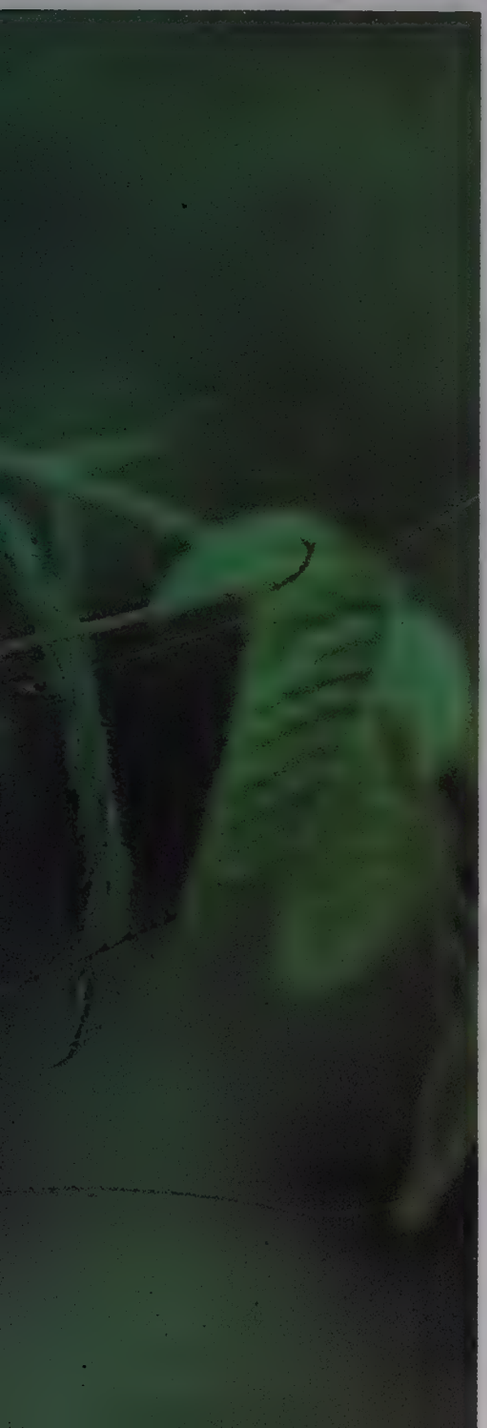
Stillness is perhaps the essential quality of the stick insect. I once saw a living specimen that was being used as one of the structural supports in a spider's web. Occasionally, a stick insect will sway as if tossed by a breeze, but otherwise it spends its daylight resting time motionless, often contorted in remarkable postures to conceal its "insectness." Legs, for instance, can be dead giveaways. Stick insects eliminate the problem by stretching out, their front legs forward and hind legs rearward, sometimes pressed close to the plant.

The main body, too, no matter how well camouflaged, might still cause a telltale thickening of a branch and so must be projected or suspended at an angle suggestive of a sprouting twig. Males of one species actually grasp plant stems with the genital claspers they use to grip females during mating and, so anchored, stick out stiffly into the air. Even in the grip of a predator, a stick insect sometimes retains its sticklike rigidity. When working with captive Mexican jays, I have often seen birds familiar with stick insects picking at twigs of the insects' host plant, apparently confusing the vegetable for the animal. On occasion, I've noticed the birds drop stiff insects, perhaps making the opposite mistake.

A number of species, several from Micronesia, have added hardened spines and "armor plate" to their body design. The spines not only break up the outline of their cryptically colored bodies but also are sharp enough to pierce the tender paws of insectivorous mammals. The great spines on the legs of one species can draw blood from a careless finger and were used by the indigenous people of Goodenough Island as fishhooks.

As impressive as stick insects' poses and disguises are, they don't always work. Fortunately for the insects, they also have an array of physical and chemical strategies to avoid being eaten. Birds—the insects' chief predators—tend to be nervous, and stick insects have ways of making them jump. Some flightless stick insect species have retained wings that unfurl rapidly, with a startling sound and a flash of bright colors and bold patterns.

Some stick insects' bright colors are bluffs, but others advertise genuine and potent defenses. One blue-green, black, orange, and red species of the North Moluccas has fury behind its flash: from two glands just behind its head, this insect can project foul-smelling vapors up to twenty inches forward and backward. Less dramatic looking, but just as capable a squirter, is a pudgy brown-and-white species from the southeastern United States.



Neither rain nor fear of predators keeps these North American stick insects from mating for a prolonged period.
Stephen P. Parker; Photo Researchers, Inc.

The active ingredient of its spray, anisomorphol, acts as an irritant, deterring birds, mice, ants, and beetles.

Still other species use a shorter-range chemical weapon in the form of distasteful additives mixed with their own blood. One, a native of New Mexico's arid grasslands, can force drops of viscous yellow blood through the joints of its legs and the places where the plates of its exoskeleton come together. This blood (actually hemolymph, the circulating fluid in insects) is apparently repulsive to predacious ants, which, if they touch the fluid with their mouths, will drop their intended prey and rub their jaws in the sand.

Like their distant relatives the grasshoppers, stick insects can spit, or more accurately vomit, when harassed. The fluid from at least one species I know well—*Diapheromera veliei*—is considered inedible by insect-eating mice, which sometimes carefully pull out the insect's gut before sitting down to their meal.

Living the life they do—nearly motionless for hours, only infrequently and slowly walking from one resting spot to another, their bodies swaying like twigs in the wind—stick insects give an impression of patience, almost forbearance. Their capacity for prolonged sexual coupling is equally impressive. Depending on the species, male and female may remain attached for hours, days, or even weeks. At present, the New World record is five weeks. This effort, however, is surpassed by an Indian species, in which the pair mate for up to seventy-nine days.

A male stick insect certainly doesn't need weeks to ejaculate. In fact, a male riding about on a female and attached to his mate by genital claspers only periodically inserts his penis. Why, then, does he stick so closely to his mate? One possible explanation that I have considered in my work is that stick insects may be seeking security through coupling. Could it be, for example, that members of species with powerful sprays are pooling their chemical weapons in a defensive alliance?

Cooperation to form a living fortress is unlikely to be the sole purpose behind prolonged matings; otherwise, homosexual couples would be a common sight. But the increased safety enjoyed by a mating couple might have driven evolution to take what was initially a brief interlude and

Günter Ziesler

The cryptic posture and color of many stick insects make them nearly impossible to see in their natural environment, such as a stand of grasses in Brazil, left. But if discovered, they are still far from helpless. Some, like this individual from West Australia, below, rapidly unfurl brightly colored wings and swish them about to startle predators.

Jan Taylor; Bruce Coleman, Inc.

tretch it out. In some cases, both partners nay benefit. Whatever their particular attery of weapons, the two together can ut up a more formidable defense. Also, a nating pair is unwieldy, and the increased umber of waving and grasping legs is isconcerting.

In one species at least, one partner fares etter than the other. *D. veliei* is a desert pecies with days-long matings. It has no otent spray, but it does vomit distasteful luid and drip noxious blood when attacked, and it has spines on its legs. It is lso relatively big (three and a half inches ong), the female being larger than the nore slender male. For much of the year, oth sexes are equally abundant and appear to be preyed on more or less to the ame extent. But when local birds, such as western kingbirds and flycatchers, are feeding their fledglings, females become scarce. Perhaps birds hit harder on females because they are meatier.

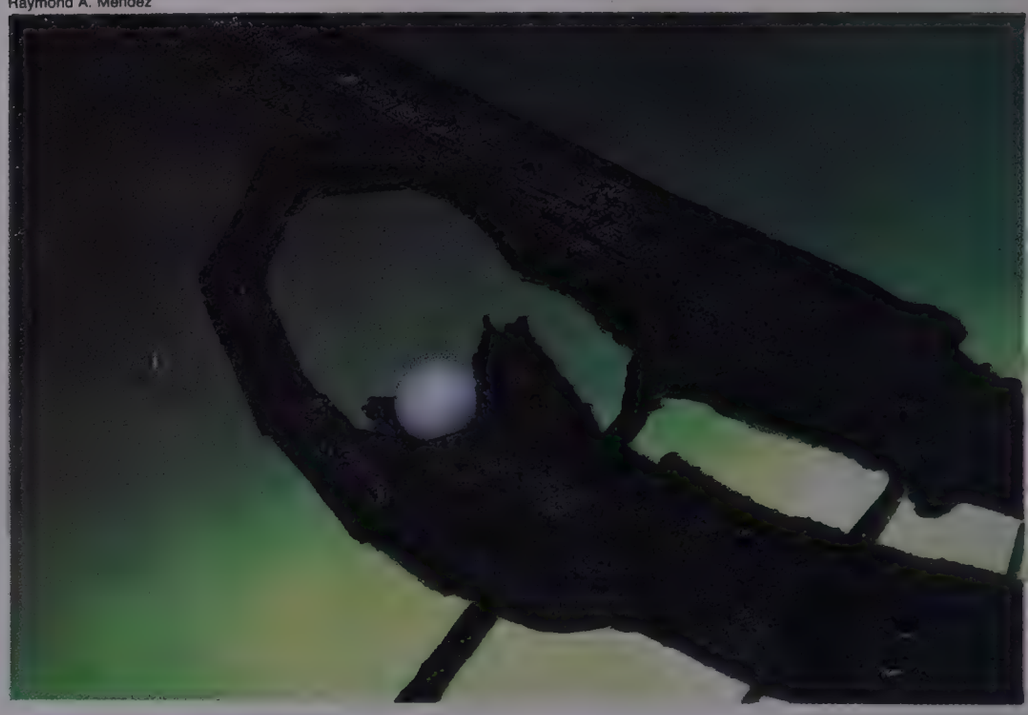
One refuge open to the female *D. veliei* may be her mate. Armed with blood, vomit, and spines, he stands upon her back like a shield. Perhaps as important as any of his weapons, when attacks come from above, he is in the way. Unfortunately, in this case the male derives little security from the sexual union. If a bird manages to hang on to a pair of mating *D. veliei,* it is generally because it has a good grip on the male. The bird may fly with its awkward catch to a feeding perch and dine on the male, while the female, along with discarded male limbs and other bits of unappetizing rubbish, falls away.

Could males have evolved long copulations to protect their mates and not themselves? Under certain circumstances, yes. Females are often less abundant than males and thus great prizes. For a male lucky enough to inseminate one, any sacrifice—even his life—to protect her, and thus his genetic future, may be worth it.

There is, however, another, equally satisfying explanation for protracted copulation. Perhaps it is not the female's life that is being guarded, but rather the male's sperm. The immediate fate of insect sperm after mating is not like that of their human counterparts. Instead of striving to fertilize an egg quickly or dying in the attempt, most insect sperm are held in receptacles that branch off from the female's interior egg-laying tube. Sperm are

A male stick insect from Trinidad transfers his sperm capsule to his mate, below. Males of most species are smaller than the females, as in the odd couple at right.

Raymond A. Mendez



released to fertilize eggs only when the eggs are being laid. In some insects, sperm may wait years for release.

If a female mates only once, the male can ejaculate and then leave to hunt for more females. His sperm will be left undisturbed to do their work when the time comes. But what if a female remates? Unfortunately for the first male, his sperm are often displaced, replaced, blocked, or removed by the next male to come along. For example, some damselfly males use comblike structures on their intromission organs to rake out any sperm left by predecessors before depositing their own. In other insect species, old sperm may be crammed to the rear of storage organs, unlikely ever to reach an egg.

So a male whose mate may copulate again faces a dilemma: should he use his time and energy to mate with many females, trusting to the odds that at least some of his matings will lead to offspring, or should he concentrate on preventing his present sexual partner from mating again? Often, guarding an already inseminated female turns out to make the most sense.

Guarding can be done in a number of ways. A male honey bee simply detaches his penis and leaves it as a plug inside his mate, a fatal subtraction (for after giving up his penis, the male dies). Similarly, a tiny Canadian fly allows his mate to pierce his head and suck up his body fluids as they mate, until all that remains is his empty shell hanging from her genital tract, effectively blocking access to it. Less drastic are the plugs and glues used by some other males; diving beetles, for instance, smear white "cement" across their mates' rear ends.

Rather than leave behind a body part or substance to do the job, some males stay with their mates and, at least for a time, protect their paternity themselves. Few, however, hang on to their mates as long as stick insects do. Why? Unlike the many insects that lay batches of eggs at a time, female stick insects often drop only a few eggs a day. Depending on the species, adults live for several weeks to several months (female *D. veliei*, for example, live an average of eighty-three days), and given a chance, females will mate more than once. There is thus no safe time for a guarding male to dismount and move on. And since any new female would produce eggs in the same way anyway, he might as well stay put. Unless, of course, rivals are few. In that case, it may be safe to leave one mated female and go off in search of others. Research with *D. veliei* suggests that they are flexible: males appear to cut short their couplings when caged alone with multiple females and extend copulations when other males are introduced.

Under normal, natural conditions, however, such sexual freedom is seldom possible. For much of the year and in most places, competition is fierce because adult female *D. veliei* are rare, relative to adult males. The ratio may be even more lopsided in other species: one female from the Seychelles was found with six males dangling off various points of her abdomen and a seventh was standing nearby. Competition could be responsible for the stretched-out mating times we now see with stick insects.

A few cases of ferocious combat between males have been observed. Two male *D. veliei*, for example, may attach themselves to the tip of a female's abdomen with their genital claspers, then hang freely, forcing the female to support their combined weight while each boxes with his front legs and attempts to puncture his opponent with spine-studded middle legs.

Although no one knows for sure yet, the female's role appears to be a passive one. Even during combats, she will continue to feed, her jaws working unfalteringly as she carries about the thrashing and sometimes bleeding combatants. Unlike many other female insects, she does not seem to choose a mate from among her suitors or to discourage any passing male from mounting her. Perhaps, for stick insects, the time and energy required to pick the best and fight off the rest is more profitably spent producing young, or perhaps the protection that any male can provide against bird attacks is most important.

In the end, stick insect behavior retains a certain ambiguity that seems fitting for creatures that survive largely by misdirecting attention through false appearances. We know that the world of stick insects (whose unusual looks and calm demeanor sometimes lead to their being kept as pets in England) is not entirely placid. And we can be pretty sure that their marathon couplings are not the result of mere inertia. But whether predation or sexual rivalry, or some combination of the two, is responsible, we don't know; these insects haven't yet divulged all the secrets of their amorousness. □

In a painting, circa 1915, by William Herbert Dunton (1878–1936), Sioux and their allies attack Custer and his troops on Last Stand Hill.

Courtesy of Buffalo Bill Historical Center, Cody, Wyoming

Bloody Knife's Last Stand

The scout and his friend Custer shared the same enemies and fate

by J. Daniel Rogers

On June 25, 1876, two men died along with many others on the grassy plains near the Little Bighorn River. One was a brilliant and brash young veteran of the Civil War; the other a respected Arikara warrior. They clashed in mortal combat, but not with each other. Lt. Col. George Armstrong Custer and Bloody Knife were not enemies; they were allies and close friends. Together they fought the Sioux (Dakota) and Cheyenne in the most famous battle of the American West.

Riding a wave of boundless aspirations as the leader of the Seventh Cavalry, Custer sought a victory that he hoped would catapult him into the presidency. Bloody Knife, less blinded by ambition, knew impending folly when he saw it but was bound by his warrior's honor, respect for Custer, and an authentic desire to defeat the Sioux and their allies. On the morning of June 25, even before coming into sight of the Sioux and Cheyenne camp, Bloody Knife said, "I shall not see [the sun] go down behind the hills tonight.... I am going home today, not the way we came, but in spirit, home to my people." Custer expressed no such apprehension.

Also known as Tamena Way Way or Nes I Ri Pat, Bloody Knife was born in the early 1840s to a Sioux father and an Arikara mother. He spent his childhood among the Sioux, where he endured much ridicule because of his mother's tribe (she may have been brought to the Sioux as a captive). Eventually, Bloody Knife and his mother returned to the Arikara, with whom he spent the remainder of his life as a mortal enemy of his father's people.

Bloody Knife may have held a personal grudge from childhood against the Sioux, but his real enmity came from the generations-old conflict that raged between the Arikara and the Sioux. Unlike the nomadic Sioux and many other Plains tribes, who hunted bison over a vast territory, the Arikara and their neighbors, the Mandan and Hidatsa, lived in fortified earth lodge villages along the Missouri River in present-day North and South Dakota. In the river bottomlands they planted maize, beans, squash, tobacco, and other crops. While the palisades around the villages offered some protection, the Arikara and

The exploits of Bloody Knife, who was a scout for the U.S. Army, were copied by Philetus W. Norris from the Arikara warrior's original robe. One scene, below, top, shows Bloody Knife (right) about to strike, but not kill, an enemy, an action known as counting coup. Another scene, bottom, shows Bloody Knife scalping a man described as an army officer. Right: Two prominent chiefs at the Battle of the Little Bighorn, Crazy Horse and Sitting Bull, are portrayed in an illustration by Amos Bad Heart Buffalo (1869–1913), an Oglala Sioux historian.

National Anthropological Archives, National Museum of Natural History

their neighbors were easy targets for the raiding Sioux.

Often their villages were under siege by the nomadic groups, making it difficult to venture out even to tend the crops. About 1804 the trader Tabeau said that the Sioux "steal the [Arikara] horses and they beat the women and offer with impunity all kinds of insults." More than once the Arikara endured this treatment rather than shatter the fragile peace and suffer the consequences of new raids by the mobile and more numerous Sioux. At other times the Arikara swiftly retaliated. In this world of conflict, Bloody Knife gained a reputation for bravery and ruthlessness.

There were few whites in the plains region of Wyoming and the Dakotas before the 1700s. The first to arrive were not geared toward settlement but sought to trade in the products of the prairies and rivers, principally furs and hides. For more than a century, Native Americans dictated the terms of trade. The Arikara, Mandan, and Hidatsa villages were especially well known as trading centers, acquiring furs from the nomadic groups to the west and trading them to the whites. For a time, the village groups enjoyed a certain affluence from their intermediary role. In 1805, when Lewis and Clark passed through the villages en route to the Pacific, a member of the expedition described the Arikara as "the most cleanly Indians I have ever seen on the voyage; as well as the most friendly and industrious."

Unfortunately, epidemics of Old World diseases raged periodically through the settlements. Smallpox, cholera, measles, and other diseases were especially deadly in the tightly packed villages. By 1794, the number of Arikara villages had been reduced from eighteen or more to only two. The epidemics did not sweep as fiercely through the Sioux, who lived in less dense, highly mobile settlements.

Trade relations soon deteriorated as well. The War of 1812 interrupted fur sales to England. Demand for furs from the Plains dropped sharply, and the trade in European and Euro-American weapons, tools, and luxuries that the Arikara had come to depend on dried up. The Arikara attributed the situation, in part, to a Euro-American unwillingness to barter.

Although the drop-off in trade lasted only a brief time, pressure on the Arikara accelerated as whites continued to push west. The Arikara tried desperately to restrain white trading parties, but the frontier had moved west, and their favored trading position vanished. Arikara hostility toward whites continued to grow, and for a long time the Arikara were known among white traders as the "horrid tribe." What the Arikara called the traders is not recorded.

By the 1860s and 1870s, promoters and politicians had repackaged the wonders of the western landscape—once known as the Great American Desert—as prime farmland free for the taking, and easterners and newly arrived immigrants began coming to this promised land by the tens of thousands. As many pioneers came to understand all too well, the Great Plains were not empty. This vast region was the ancestral homeland of many Native Americans. For the Arikara and their neighbors, these were times of famine and intermittent warfare with other tribes.

Having accepted whites as necessary allies against the Sioux, the Arikara, along with the Mandan and Hidatsa, moved for

Courtesy of Leslie Tillett, *Wind on the Buffalo Grass*

protection into Like-a-Fishhook Village at Fort Berthold. The similar life styles of these three tribes allowed them to band together against the Sioux as a means of fighting off their continuing raids.

Beginning in 1868, the Arikara were invited to enlist as scouts in the United States Army at Fort Stevenson. Among the first to enlist were members of a warrior group that functioned as a tribal police force under Chief White Shield. Most were experienced warriors. Although they debated the decision to work with the soldiers, few of the White Shield warriors wanted to pass up an opportunity to fight the Sioux while getting paid.

Scouts functioned in the most dangerous roles. They carried mail, conducted reconnaissance far ahead of the main column of troops, and served as early warning sentries at camp outskirts. Their roles became even more important when, because of growing hostilities between the Sioux and whites, Custer and the Seventh Cavalry transferred to the Dakota Territory in 1873. As Bob-tailed Bull, a leader of the scouts, said to Custer, "My brother . . . I have had experience fighting the Sioux, and when we meet them we shall see each other's bravery."

Custer had graduated last in his class at West Point but, through his Civil War exploits, rose to brevet brigadier general by the age of twenty-three. When assigned to the northern Plains, he already knew a great deal about Indian warfare in the western territories. Between 1864 and 1873 he had been stationed in Texas, Kansas, and Kentucky. In Oklahoma he led the Seventh Cavalry in the Battle of the Washita.

Ostensibly brought in to maintain the peace, the increased military presence on the northern Plains was intended to clear the way for additional westward expansion of the United States. In 1873 the Seventh Cavalry helped the Stanley Expedition survey a railroad route along the Yellowstone River. Just a year later Custer and his regiment prepared to hit the trail again, this time to the Black Hills, deep within the Sioux reservation.

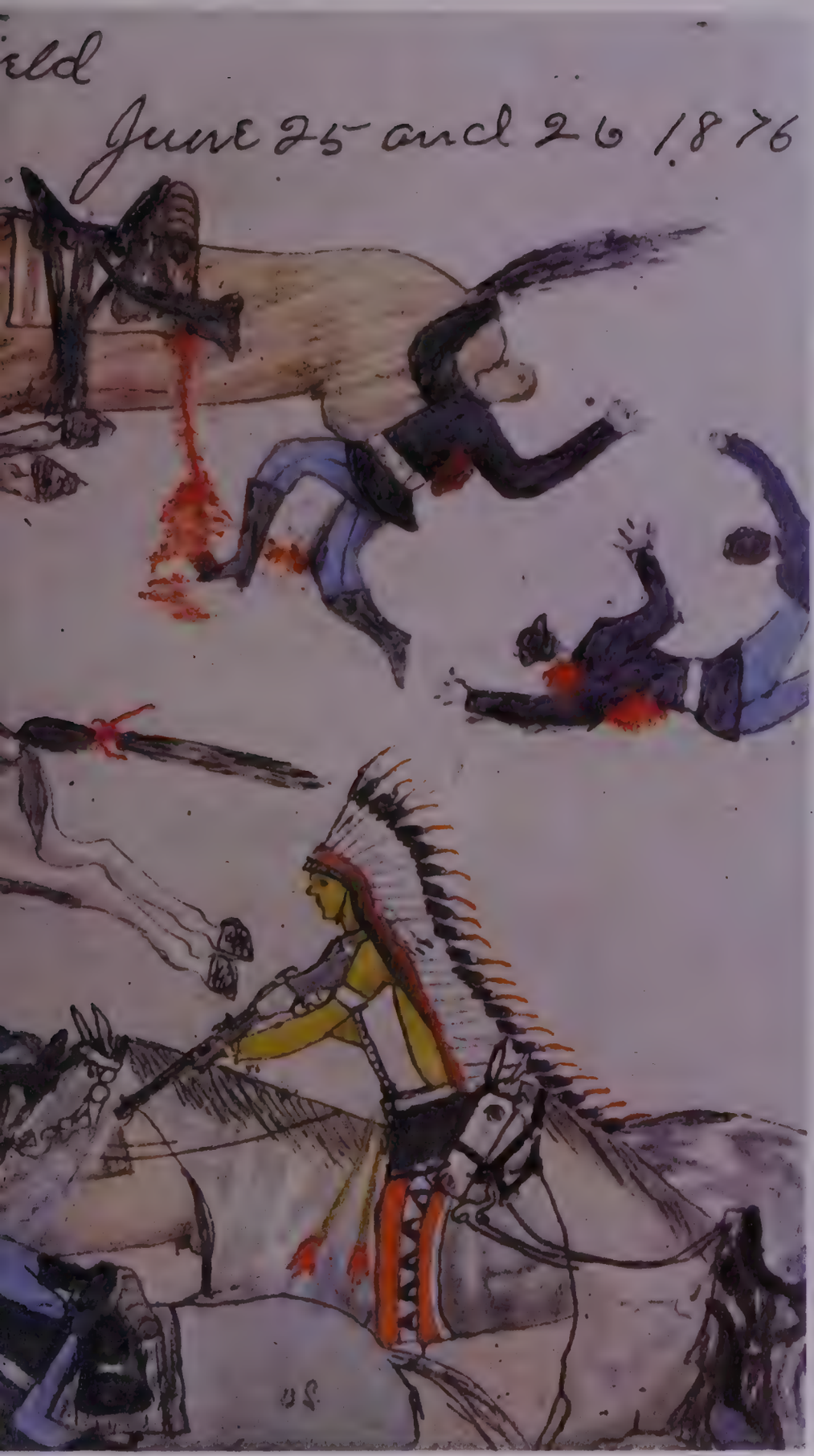
By this time, Bloody Knife was Custer's friend and chief scout. The *Bismarck Tribune* for April 29, 1874, singled the scout out for special mention, reporting that "Bloody Knife who was of such great value to Gen. Custer last summer, on the [Stanley] expedition, is expected in a day or two to enlist." For his valuable services Custer bought Bloody Knife a gift and arranged for additional compensation.

Like Custer, Bloody Knife had a complex personality, not always marked by good judgment. Unlike most Arikara, Bloody Knife developed a drinking habit that sometimes brought him to the brink of disaster. On June 2, 1875, the *Bismarck Tribune* reported that a Missouri River steamboat captain had refused him passage because of his drunkenness. In anger Bloody Knife exchanged gunfire with the crew. Fortunately, all escaped injury.

The historical records made by whites detail few of Bloody Knife's exploits; luckily, however, we know of another official document that recorded his story—Bloody Knife's "war robe." This was a special robe made of several hides sewn together and covered with drawings depicting his exploits. Designed less for its visual appeal than as a testament to bravery, the robe presented twenty-four independent battle scenes, not unlike the cam-

Amos Bad Heart Buffalo drew on the victors' eyewitness accounts when he created this and other depictions of the Battle of the Little Bighorn.

Courtesy of Leslie Tillett, *Wind on the Buffalo Grass*



paign ribbons, service marks, and medals earned by soldiers the world over.

About 1875, Philetus W. Norris, an amateur scientist, approached Bloody Knife in hopes of purchasing the robe; another scout, Charley Reynolds, served as interpreter. Bloody Knife refused to sell, but he did allow Norris to make a copy of the drawings on the robe. Charley Reynolds died with Bloody Knife at the Little Bighorn, while Norris went on to become the superintendent of Yellowstone National Park and later worked for the Smithsonian Division of Mound Exploration. The fate of the robe is not known, but Norris thought the Sioux might have taken it in the battle's aftermath. Fortunately, the drawings and Norris's hastily scribbled notes on Bloody Knife's explanations of some of the scenes have survived.

The robe followed an ancient Plains tradition of hide painting. Many tribes had developed distinctive styles and uses for the painted bison hides—from beautifully decorated tepees to colorful storage pouches. While many designs were identified with a particular band or tribe, others were more documentary in nature. The Kiowa tribal calendars, for example, were graphic reminders of important events in tribal history. Such paintings were often the work of a designated tribal historian. Other renderings, such as Bloody Knife's robe, were far more personal, yet followed widely recognized conventions. Clothing and hairstyles, for example, were used to indicate the tribal affiliation of the individuals depicted. The location of figures, weapons used, styles of horse gear, and other markings also helped tell the story.

All the scenes on Bloody Knife's robe depict moments of triumph. In one image, he dismounts and races toward two kneeling figures with flintlocks. To show his bravery, Bloody Knife carries his own flintlock stock first, preparing to strike, but not kill, one of the men. This type of action, known as counting coup, humiliated the opponent and conferred great honor upon the warrior. In the same scene, a warrior allied with Bloody Knife spears the other figure, who has two marks above his head, indicating he has already had two coups counted against him, perhaps

Courtesy of Little Bighorn Battlefield National Monument

Curly, White Man Runs Him, and Hairy Moccasin, below, three Crow scouts who led Custer to the Sioux camp, commemorate the forty-fifth anniversary of the battle. Opposite page: Photographed on the 1873 Stanley Expedition, which surveyed a route for the North Pacific Railroad, Bloody Knife points to a map on Custer's lap.

W. Wildschut; courtesy of National Museum of the American Indian, Smithsonian Institution

by other members of Bloody Knife's war party. The ally wears a bison headdress and carries a shield depicting a bison; he is probably a Mandan and a member of that tribe's Bison Society. Based on hairstyles, the enemies are probably Sioux.

Another scene portrays Bloody Knife's greatest feat in battle: in an encounter with nine Cheyenne, he managed to kill three of his opponents and wound another. However, Bloody Knife related to Norris that he could retrieve only two of the scalps. Norris reported in his notes that most Native Americans deemed losing the scalp of a slain enemy "a misfortune only excelled by loss of their own."

Most of the scenes involve Bloody Knife in combat with Sioux, Cheyenne, or Crow. Only one deviates from this theme; according to Norris's notes, it shows Bloody Knife's encounter with a cavalry officer, the only white man Bloody Knife claimed to have killed. The motive was revenge for the officer's "clandestine intimacy" with Bloody Knife's wife, She Owl. Bloody Knife said he took the officer's scalp.

Considering that the scouts lodged complaints detailing sexual transgressions against their wives by U.S. soldiers, and that orders were issued making the scout camp off limits, such an incident seems possible. But if Bloody Knife had killed an officer after joining the scouts, there would have been a formal inquiry, with duly recorded testimony. No such record exists. Perhaps the army did not know Bloody Knife was responsible for the death of the officer or perhaps Bloody Knife was referring to a time before he joined the scouts, when the Arikara were intermittently at war with the United States. A third possibility is that the scene depicts the scalping of a trapper named Le Franc, whom Bloody Knife was alleged to have killed in 1868.

The 1874 Black Hills Expedition, in which Bloody Knife accompanied Custer, was organized to survey the region and verify earlier reports of gold there. Custer confirmed the reports, and when the news hit the East, a headlong push opened the area to mining and settlement, despite treaties that promised the Sioux inalienable rights to these lands. Hostilities grew, and in the summer of 1876, the army began a campaign in the Black Hills to "end the Indian threat." Bloody Knife and the other scouts took their place ahead of the advancing columns.

Custer had sought command of the entire expedition, but his inclination toward brash action nearly cost him any role at all. Ultimately, he was allowed to retain command of the Seventh Cavalry. Ambition kept his spirits high. He saw the venture as a chance to get some perfectly timed publicity, just what he needed to capture the nomination for president at the Democratic convention later that summer. Custer gave Bloody Knife a handkerchief and medal and told the assembled scouts that if he could win even a small victory he would become Great Father, president of the United States, and that Bloody Knife would accompany him to Washington.

Early on the morning of June 25, the scouting vanguard sighted a vast camp of Sioux and Cheyenne. Custer, sensing a quick victory, pushed ahead without waiting for reinforcements. The scouts warned of the enemy's strength, but there was no turning back. The well-known results were catastrophic for the army and stand as a heroic and important symbolic victory for Native Americans (*see* "Post-mortem at the Little Bighorn," *Natural History,* June 1986).

Custer and his detachment died on a knoll above the Little Bighorn River. Bloody Knife fell in a grove of cottonwoods, along with some members of Major Reno's detachment, which had crossed the river but was then forced to retreat. One story told by the Sioux states that Bloody Knife's head was severed and taken back to camp as a war trophy.

Bloody Knife and the other scouts who rode with Custer lived during a time of change. Warriors all, they sought to bring honor to themselves and their families through success in battle against the Sioux and Cheyenne. But government agents were already planning the breakup of native communal life and property. The government imagined a future of separate, well-controlled, acculturated Native American families, each farming a plot of land. Soon the Sioux and Cheyenne would be forced to accept defeat, and there would be little call for warrior skills. The realities of reservation life presented new and harsh challenges that could not be dealt with in the old ways, challenges that the Arikara and their neighbors still struggle with today. □

A lone common tern stands amid a group of black skimmers on a barrier beach off Long Island, New York. Before nesting, the birds will stake out small territories.
Joanna Burger

Terns for the Better

For black skimmers, nothing beats sharing a beach with thousands of noisy, aggressive common terns

by Joanna Burger and Michael Gochfeld

As the sunset reddens the rolling dunes, an onshore wind bends the wispy beach grass. The waves of the rising tide cascade over the beach, muting the cries of common terns flying in from their last feeding trip of the day to the colony a hundred yards from shore. Nestled between grassy foredunes and back dunes cloaked with angular pine trees and rounded bayberry shrubs is one of the largest common tern colonies in the world. More than 5,000 pairs of these small, black-capped seabirds make their nests—slight scrapes or depressions in the sand or grass—on a half-mile stretch of Cedar Beach, on a barrier island off Long Island, New York.

On this late May evening, nesting is well under way, and the tern colony is frenetic. Some of the male terns carry fish to their mates at the nest; some males and incubating females fiercely defend their territories from intruders—usually other terns that venture too close to the nest scrape. Near the center of the colony stands a group of more robust birds, twenty-six black skimmers. They face into the wind, their jet black backs and white undersides contrasting with their vibrant red bills. Each bird, although it seems to stand randomly within the flock, is actually one of a pair and is slightly closer to its mate than to its neighbor. The sexes are easy to distinguish, for the male is a third larger and heavier than the female and his bright red bill is longer. About 200 pairs of skimmers share Cedar Beach with the terns. They tend to be found in groups of a dozen to forty pairs and always nest in the most open spaces of the colony.

Some miles away, on Barnegat Bay off the coast of New Jersey, other congregations of terns and skimmers are also in the midst of nesting. These colonies are situated on salt marsh islands, rather than a barrier beach. The nests are placed, not among dunes and tall beach grass, but on mats of dead eelgrass, strewn upon the marshes by the high, stormy tides of winter, and on the surrounding *Spartina*, a short, tough marsh grass. Because they have withstood the high tides of many years without being washed away, old mats are wide and bleached white by the sun. Nesting on such mats gives the birds

some insurance against the high tides that wash out eggs and chicks nearly every year in some colonies.

Along the Atlantic coast from Florida to New York, black skimmers almost always nest within colonies of terns. The reverse is not true, however; common terns often nest without associates. We have spent twenty years studying the nesting association of these two species in New York and New Jersey. Since 1976, we have found common terns nesting at more than a hundred sites on salt marsh islands, spoil islands, and barrier beaches in coastal New Jersey. Skimmers nested at only thirty-seven of these, almost always in a tern colony on a salt marsh island. Do skimmers pay a price for nesting where they are vastly outnumbered by terns? Or are there advantages to this arrangement? To find out, we observed several colonies over many breeding seasons, from April, when the birds first arrive, to late summer, when they desert the colony. In autumn, skimmers travel to the southern United States, and terns migrate to their winter quarters in northern South America.

One dynamic of the mixed colonies was obvious. Skimmers tended to be in the center, while terns occupied the periphery. This held true for both beaches and salt marshes. On salt marshes, a secondary sorting out was apparent. Skimmers predominated on large central mats of eelgrass; terns on smaller mats. We wanted to know whether this reflected the habitat preferences of the birds or was the result of competition between the species.

Both skimmers and terns are territorial, so sharing a colony inevitably entails some competition for nest sites. Skimmers arrive at the colony somewhat earlier than the terns and stand around the beach or marsh. When the terns begin to settle into the colony in considerable numbers, groups of skimmers shift to a centrally located open patch of sand or a wide mat of marsh vegetation. Simple colony occupation then gives way to the serious task of territory acquisition. Both species spread out and begin to defend individual territories, skimmers predominating in open patches on the beach and wide mats on the marsh, ringed by terns. The thin boundary areas between skimmers and terns are the sites of most of the turf battles.

For both species, displays, chases, and overt attacks, which we observed from our blind, are means of acquiring territory. Only the males vie for territories early on. But after pair bonds are fully renewed (the same pairs remate year after year), both sexes of both species defend their turf. In early to mid-May, skimmers defend territories against the smaller terns nearly as often as against other skimmers. With females weighing about half a pound and males about three-quarters of a pound, skimmers usually defeat the quarter-pound terns, even though they settle on the mats a few days later than the terns. If territorial disputes continue through the breeding season, young chicks that wander from their nest can be injured or killed by aggressive neighbors. The larger skimmers have the edge here. They occasionally prey upon and devour tern chicks in nearby nests; terns peck at and can injure skimmer chicks but don't eat them.

From 1983 through 1986, we built mats of different colors and sizes on several

Dan Guravich

Week-old skimmer chicks seek relief from the heat in the shadows cast by their parents, left. These skimmers nested on a shell-strewn habitat in Texas. On salt marsh islands in the northeast, skimmers and terns vie for nesting sites on raised grassy wrack, below.

Joanna Burger

New Jersey salt marsh islands in an attempt to distinguish competition from preferences. In April, before the birds arrived, we fabricated white mats from old, decayed, and bleached eelgrass left behind by winter storms in previous years, and dark mats from fresh eelgrass strewn on the marsh by recent high tides. With a dozen people using two boats, we placed the mats on four matless islands.

We waited anxiously to see if the terns and skimmers would accept our handiwork. By early May, our labors were rewarded. Incoming terns took up residence all over the mats, but a few days later bands of skimmers, which had been standing placidly along the shore and on the mud flats, staked claims and scattered the terns from the widest mats. After minor territorial clashes, the birds sorted themselves out, with the skimmers in the center and terns everywhere else. All of the sixty-four skimmer nests were on white mats, nearer the center, and 73 percent of the tern nests were on white mats, nearer the edges. Moreover, the pale skimmer eggs, but not the dark tern eggs, were well camouflaged on the white mats. Skimmers, at least, preferred wide white mats and may well have been excluding the terns. But would terns nest on wide mats in the absence of skimmers?

This part of the experiment had to wait until the next year. We constructed new mats, some narrow (three feet wide) and some broad (twelve feet wide), and placed them on three islands in Barnegat Bay. All mats were separated by about six feet of marsh grass. This, we reasoned, would give the terns and skimmers a choice. On only one of the islands were there no skimmers. And here, terns nested all over even the wide mats. We had our answer; when skimmers are present, they drive the terns from the center of large mats.

Over the years, our observations of aggression and territorial clashes and our experiments with mats of different sizes, shapes, and colors indicate that skimmers and terns do indeed compete for mat space and that skimmers usually win the best places. Other dynamics also became apparent as we watched the day-to-day interactions of mixed colonies.

Both terns and skimmers fish in estuaries, bays, and the open ocean. During courtship, tern and skimmer males bring fish to feed their mates, thereby contributing to the production of the females' eggs. Skimmers usually lay three or four eggs, although in good food years a few may lay five or six. Throughout the colony, females stand patiently on territories, waiting for males to return with fish. The male skimmer flies out to a salt marsh creek or shallow bay and skims along the water's surface, his lower, knife-edge bill—longer by about an inch than the upper bill—slicing the water, ready to grasp a fish.

As if somehow coordinating their fishing efforts, several skimmer males return to the colony together. After exchanging vocalizations with the females, the males present the fish to their waiting mates, who turn and crouch, allowing the males to mount. Copulation ensues, accompanied by staccato calls and a characteristic wing-flapping display visible across much of the colony. This display seems to excite neighboring pairs and may contribute to synchronizing reproduction.

But so many birds returning with fish makes piracy a temptation, and some terns, and even a few skimmers, prefer to steal fish from a bird in flight rather than forage on their own. Piracy has a greater cost for the terns (on some days up to 16 percent of their fish are pirated) than for the skimmers (only one percent). Skimmers bring back relatively large fish for their mates (averaging more than three inches), switch to much smaller fish (one to two inches long) when they have baby chicks, and gradually increase the fish length to four to five inches as the chicks grow. Pirates, on average, steal fish that are three to four inches long; in other words, they steal when they can obtain enough food to make it worthwhile. Nonetheless, skimmers only lose food to other skimmers, and they are not particularly successful at stealing from terns, so the costs of piracy are not greater for skim-

Named for their fishing technique, skimmers ply open water with their long lower mandible. When a fish is intercepted, the skimmer flips it into its beak and carries it back to the colony.
Dan Guravich

mers that nest with terns than for those that might nest alone.

After being incubated for about three weeks, skimmer eggs begin to hatch in mid-June. Parents make soft mewing noises in response to the begging calls of chicks. The female begins incubating after laying the second egg of her clutch, so that her first two chicks hatch an hour or two apart, but the third hatches a day later, and the fourth, if it hatches at all, still a day later. Such asynchronous hatching results in nestlings of different sizes. Nearby, other pairs incubate eggs, feed or brood tiny chicks, and stand guard over larger ones. A few yards away, common terns, which lay eggs and begin their twenty-four-day incubation earlier than the skimmers, return to feed their already two-week-old chicks, which beg by jumping up and down and calling loudly.

As we watch from our blind, the colony abruptly falls silent and hundreds of terns take to the air, first circling in a random fashion, and then coalescing noisily around a dark female marsh hawk flying low over the colony. The skimmers, too, take wing, but they fly in a dense flock away from the colony and over the beach and waves. Making large, sweeping circles, they avoid the hawk but hardly contribute to the colony's defense. Despite the loud calls and diving attacks by the terns, the hawk plunges to seize a small tern chick and sails out of the colony with the victim. On rare occasions, these hawks actually seize adult terns out of the mobbing flock.

Because terns and skimmers nest out in the open, they attract a host of predators. The New Jersey and New York colonies we studied endured the depredations of herring gulls, ruddy turnstones, marsh hawks, great horned owls, cats, dogs, minks, and foxes. Although skimmers are as aggressive as terns in claiming nesting territory, they are far less assertive with predators. Common terns mob, circle, and dive at most predators that enter the colony. They are most aggressive when their chicks are small, and they modify their approach according to the type of predator. If the invader is a cat, dog, or hawk, the birds usually circle well above it, but if the predator is not big or scrappy enough to hurt them (a gull, turnstone, squirrel, or crow), the adult terns dive directly, often hitting the intruder on the head or back with their bills. Fifty or sixty terns may circle above a marsh hawk, but they will make only eight to ten dives in any minute; in contrast, only twenty or thirty terns may circle a herring gull, dive bombing it seventy or eighty times a minute.

Many but not all predators leave the colony when pursued by terns. Even human intruders are intimidated. We have seen children running frantically for the edge of the colony, pursued by twenty-five or thirty diving terns. Responding to similar human invasions, skimmers merely circle low over the far dunes or ocean, returning only minutes later to swoop, but rarely, if ever, attempting to strike. A skimmer may defend its nest by giving an elaborate, injury-feigning distraction display, dipping to the ground, flopping its wings, dragging its feet, and pressing its body to the sand or pattering its feet as if it were too heavy to take flight. If a predator comes too close, the skimmer flies safely away. Such performances are characteristic of solitary nesting species (such as killdeer or sandpipers) that try to lead predators away from a concealed or cryptic nest. Distraction displays by skimmers indicate that they are not as closely related to terns and gulls as we once thought.

While their distraction displays may divert predators, skimmers rely primarily on the early warnings of their numerous tern neighbors. Biologists call this use of another species as a sentinel a form of information parasitism. Likewise, the skimmers' reliance on the terns' greater aggression is a form of social parasitism, although it does not harm the terns.

Although skimmers nesting in tern colonies must compete with terns for space and expend some energy in defending their territory and small chicks from terns, they are the clear winners in terms of gaining prime nesting territory and in being protected from predation. Overall, they pay a very small price for many clear benefits. Sharing the beach and marsh with common terns seems to give skimmers the best of both worlds. □

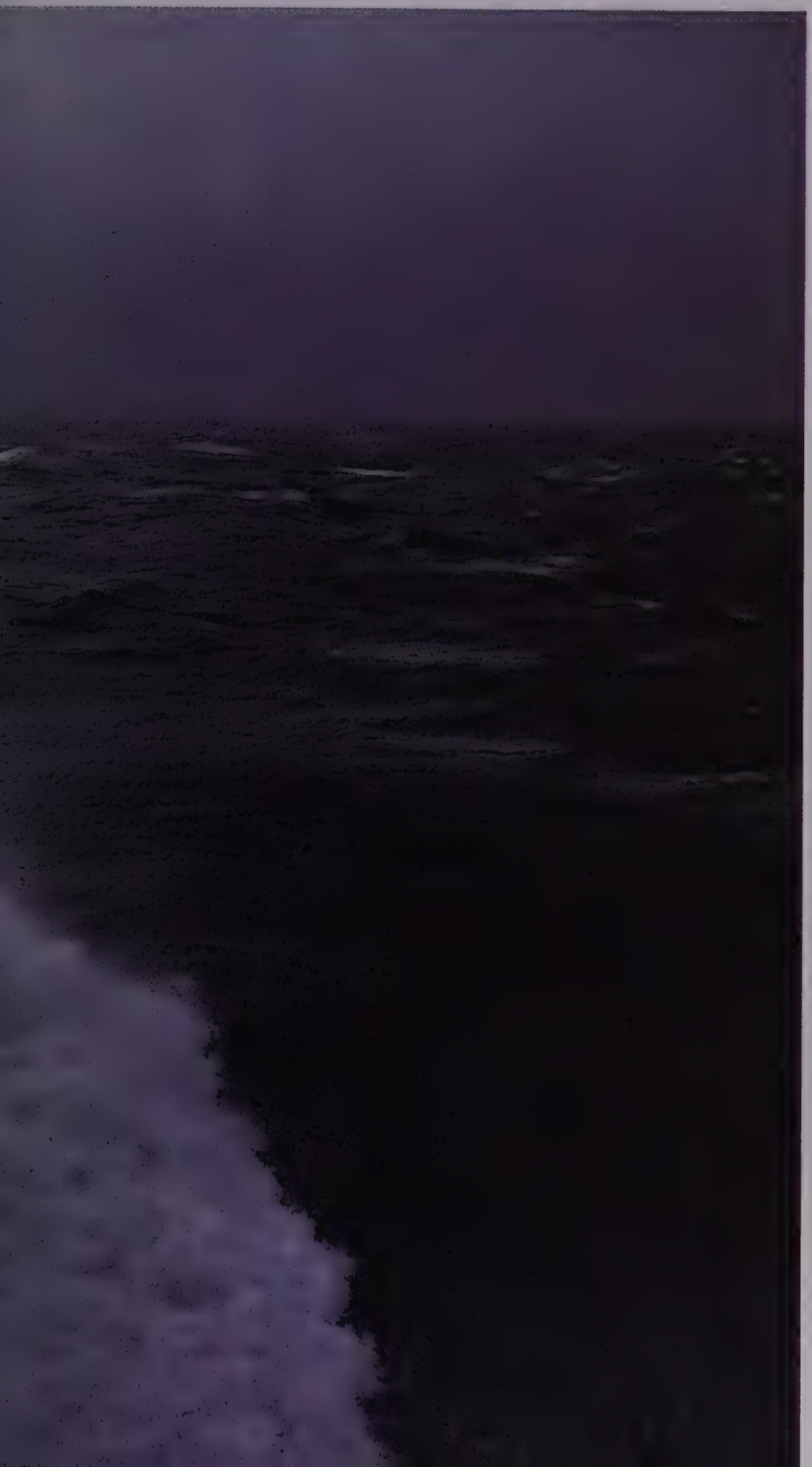
Carrying divers and equipment for underwater exploration, the USS Safeguard, *a navy salvage ship, heads across the North Pacific toward Kiska Island.*

Larry Murphy, National Park Service

Aleutian Affair

Archeologists return to Japan's World War II beachhead in Alaska

by Daniel J. Lenihan



Unconsciously sidestepping a few feet to the right, then to the left, we converse on the deck of the USS *Safeguard,* a navy salvage ship, as she is buffeted by rolling North Pacific swells. Although it is early September, visible puffs of breath punctuate Larry Murphy's words as he briefs me on the progress of a three-week expedition to locate and document remains of the only real fighting during World War II on what could be considered North American soil. We are heading west to the island of Kiska, hoping to finish survey work there and move on briefly to Attu, nearly 200 miles farther away, at the western end of Alaska's Aleutian chain. The Japanese occupied both islands in June of 1942 and were not dislodged until a year later.

Our expedition is unusual in that we are exploring underwater as well as on land. Diving rangers and archeologists from the National Park Service are aboard, including Larry, Mike Eng, and me from the agency's Submerged Cultural Resources Unit and Susan Morton from our Alaska office. Representatives of the U.S. Fish and Wildlife Service and U.S. Air Force round out the primarily navy complement of shipboard personnel.

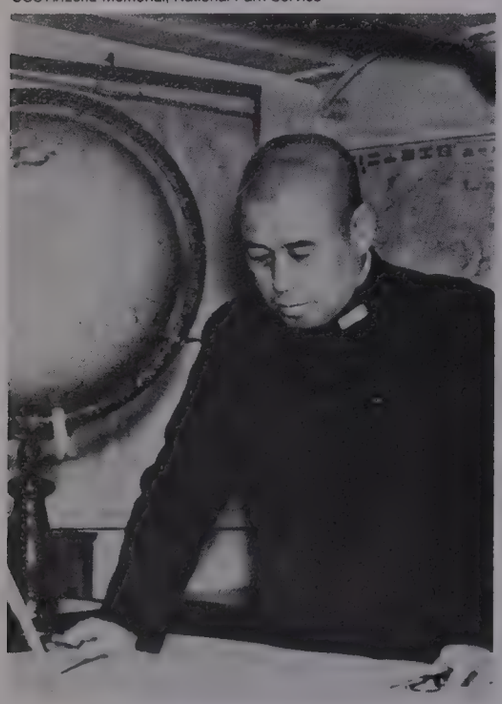
The Navy's willingness to adapt its ship schedule enables us to carry our historic preservation mission to this remote area, while providing realistic "readiness" training for navy diving and salvage teams. The navy divers are from the *Safeguard* itself or from the Mobile Diving and Salvage Unit in Pearl Harbor. The latter are men and women we have worked with before in similar ventures from Pearl Harbor to Palau (*see* "The *Arizona* Revisited," *Natural History,* November 1991).

With the tough diving conditions we are facing, the presence of the navy divers is particularly welcome. The water temperature hovers around 36° F, and the weather is alluded to in the *Coast Pilot* as "the worst in the world." In most theaters of the war, the chief adversary was the enemy; in the Aleutians it was the elements. Some air and sea engagements took place with the opposing sides never seeing each other, more faith being placed on blips on radar screens than ever before in military history. Squadrons of planes from both

The Yomiuri Shimbun

Adm. Isoroku Yamamoto, below, was the architect of the Pearl Harbor attack and commander in chief of Japan's Combined Fleet. He was killed when his plane was intercepted by U.S. fighters on April 18, 1943, exactly one year after the "Doolittle raid." Right: Japanese aircraft and crews in the Aleutians.

USS *Arizona* Memorial, National Park Service



sides were decimated when fog and 100-mile-per-hour winds caused them to miss both the enemy and the way home. Returning stragglers, out of fuel, crashed into treeless hilltops, leaving stark testimony on the Aleutian landscape of the human costs of war.

The same violent weather that confronted Allied and Japanese fliers during the war has already hampered our project. Several of my colleagues and I were stranded for four days at the naval base on Adak, an island 250 miles east of Kiska. We had hoped to get a lift on the regular Coast Guard C-130 transport plane supply run to Attu and rendezvous there with the ship. Instead, Larry finally decided to suspend operations and come get us; we are now making our way back to Kiska in moderate seas.

Larry informs me that despite the weather, he has successfully surveyed much of Kiska Harbor with side-scan sonar. He and our navy comrades have found several sunken vessels, including one submarine. The strategic bombing survey and other archival reports indicated these sites should be there somewhere, but now we know where "somewhere" is. The landlubbers have made excellent headway too; they report that the landscape of Kiska Harbor is totally dominated by the almost fifty-year-old residues of war.

In 1942, the Imperial Japanese Navy was still riding high from the attack on Pearl Harbor. Further victories in the Philippines, Guam, Hong Kong, Java, Burma; a perceived victory in the battle of the Coral Sea; and the sinking, off Indochina, of the two largest British warships in the Pacific—all made a "Greater East Asia Co-prosperity Sphere" under the aegis of Japan seem an attainable dream. Hawaii and the western Aleutians were not necessarily excluded from this vision. The prospect of a final confrontation with the U.S. Navy loomed.

The more cautious among the Japanese leaders knew that anything less than quick elimination of the U.S. Pacific Fleet would spell eventual disaster for Japan. Admiral Yamamoto, architect of the Pearl Harbor attack, was convinced that an all-out battle had to be provoked quickly, instead of being fought at America's convenience. He had spent enough time in the United States, studying at Harvard and serving as a naval attaché, to understand the overwhelming industrial capacity of that nation and to be less than confident in the view, then prevalent in Japanese military circles, that Americans lacked the will to fight.

A particularly disquieting event occurred during these months of headlong victory to give pause in this regard. On April 18, about lunchtime, sixteen American B-25 bombers appeared, seemingly from nowhere, and bombed Tokyo and several other industrial areas to the south, including Nagoya, Kobe, and Osaka. Al-

though its tactical effect was negligible, the "Doolittle raid" was a stunning and daring attack, difficult to reconcile with a spineless enemy. Also, the uncertainty of where these planes had come from raised the frightening possibility that the United States had managed to build long-range bomber bases in the Aleutians.

In reality, the planes had flown from the decks of the aircraft carrier USS *Hornet,* which, escorted by the carrier USS *Enterprise* and other vessels, had slipped to within 600 miles of the Japanese coast. The Japanese had even detected the carrier force but considered it too far away to threaten the homeland (normally, air attacks were not launched until carriers could maneuver to within 300 miles or less of their target). That the Americans would risk two carriers at this low point in the war was itself remarkable; that the payload would be twin-engine, long-range bombers never intended to fly from aircraft carriers was beyond imagining. Confusion reigned as reports of the air raids began to pour in to the high command.

Over time the Japanese became increasingly convinced that the bombers emanated from the carriers, but they could not be sure. The Aleutians were the only real alternative (President Roosevelt's helpful suggestion that the planes came from Shangri-La went unappreciated). At any rate, the raid drew Japanese attention to the north, and to the need to neutralize or forestall the establishment of Allied bases there. From the Aleutians, the Japanese would also be within striking distance of the Canadian west coast and Seattle. The light carrier *Ryujo* and the larger *Junyo,* accompanied by more than a dozen other vessels, were assigned to spearhead an attack.

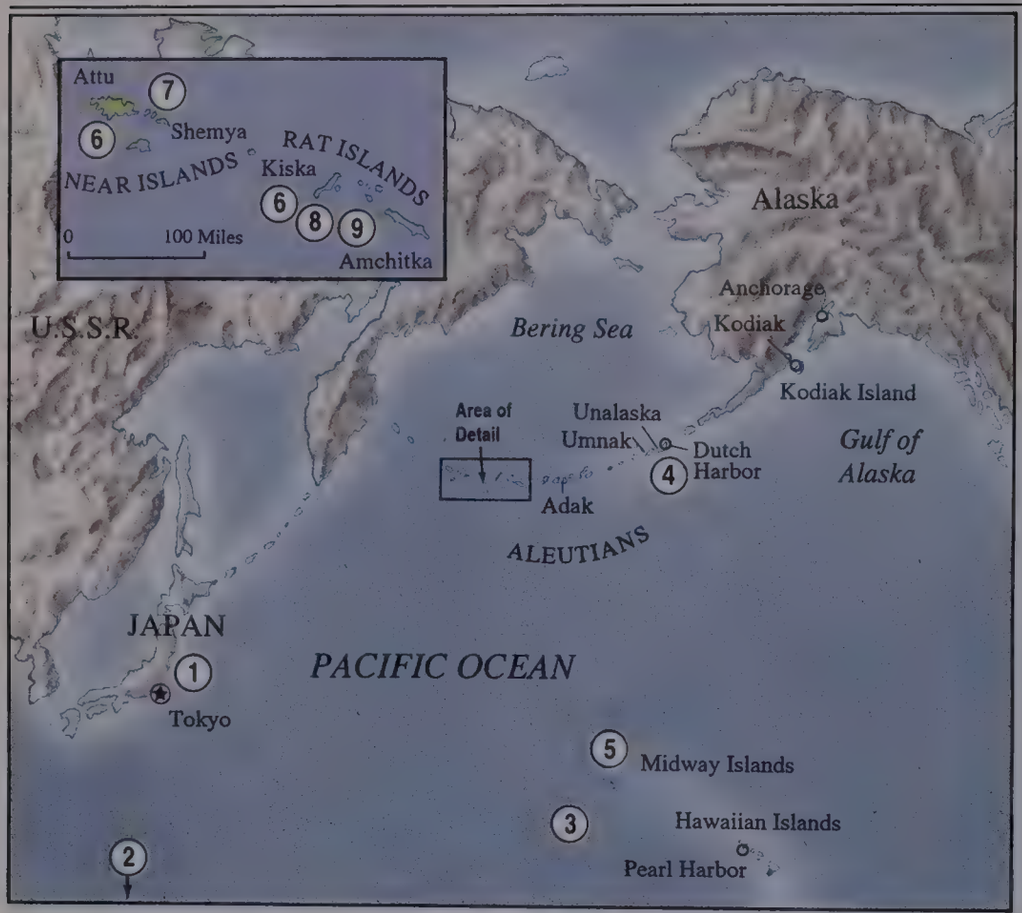
A conventional theory is that Admiral Yamamoto launched the Alaska assault to distract the American Pacific Fleet from the real Japanese target, the American naval base at Midway, an island group at the extreme western end of the Hawaiian chain. But this argument does not explain why he would have removed two valuable carriers from the main fray simply as a diversion, or how it would have helped him fulfill his stated strategy of drawing the U.S. fleet together for the big kill. In any case, the value of any diversion became moot because, unknown to the Japanese navy, the Allied intelligence community had broken the imperial code and knew perfectly well that the Combined Fleet (as the Japanese navy, exclusive of the forces in China, was referred to) was headed toward Midway.

Although stronger than the rebuilding U.S. Pacific Fleet, the Combined Fleet was operating below planned carrier strength. A month earlier, the Japanese had claimed a victory in the naval air battle of the Coral Sea, having sunk more tonnage, including the carrier USS *Lexington.* But one of their own light carriers was destroyed, and two heavy ones were temporarily put out of commission. In addition, the Aleutian contingent was off on its own mission.

Early in the morning of June 3, the Japanese initiated an air strike on Unalaska Island, in the eastern Aleutians, and experienced their first taste of the adverse environment. Of the forty-five planes launched from the carriers, one crashed immediately into the sea, and less than half were able to find Unalaska, let alone the diminutive targets: Fort Mears, an army base, and Dutch Harbor, a naval base on Amaknak Island in Unalaska Bay. And they barely made it back to their carriers through the fog before running out of fuel. For their troubles they destroyed some buildings at Fort Mears, killing twenty-five and wounding twenty-five more. Forays later in the day did little more damage, while the unexpected appearance of U.S. fighters indicated the

The Japanese invasion of the Aleutians (outlined below) may have cost them the pivotal battle of Midway. Right: In the years since World War II, the harsh Aleutian elements have nearly consumed the wreckage of the Nojima Maru, *an armed transport that was attacked in Kiska Harbor.*
R.H. Day

Joe LeMonnier



1. April 18, 1942: "Doolittle raid" bombs Tokyo
2. May 3–8, 1942: Battle of the Coral Sea (southeast of New Guinea) claims the U.S. carrier *Lexington,* but one Japanese light carrier is sunk, and two heavy ones are put out of commission and cannot be returned to service in time for the battle of Midway
3. June 3, 1942: Battle of Midway begins as Japanese Combined Fleet encounters U.S. land-based aircraft
4. June 3, 1942: Planes from Japanese aircraft carriers *Ryujo* and *Junyo* begin bombing Dutch Harbor
5. June 6, 1942: Battle of Midway ends; Japanese losses include four aircraft carriers, 332 planes, one heavy cruiser, and 2,500 casualties; U.S. losses include the carrier *Yorktown,* 147 planes, one destroyer, and 307 casualties
6. June 7, 1942: Japanese invade and occupy Attu and Kiska
7. May 11–30, 1943: Attu retaken by United States in bloody fighting
8. July 28, 1943: Kiska evacuated by Japanese forces
9. August 15, 1943: U.S. and Canadian forces retake Kiska

presence of an airfield (a new base had been established at Umnak Island).

The same morning, the battle of Midway began, with the two sides making some tentative contact and engaging in minor skirmishes. Yamamoto's fleet consisted of four of Japan's largest carriers, along with more than 100 support ships, among them the great battleship *Yamato.* The fleet was split into various components, including mobile attack and invasion forces and support groups, separate from the main body of heavy sluggers. Yamamoto's plan was to launch naval air strikes on Midway, then invade and occupy the islands, leaving the Japanese in position to threaten the main Hawaiian islands. This would force the weakened Pacific Fleet to confront the Combined Fleet, which would deal the deathblow. A peace favorable to Japan's interests in the Pacific could then be negotiated.

On June 4, however, two squadrons of American dive bombers engaged in the battle of Midway happened upon the main carrier force of the Combined Fleet—with its planes refueling on the decks. Within minutes the fortunes of war shifted. With three of his four heavy carriers headed to the bottom (the fourth soon followed, along with a heavy cruiser), Yamamoto frantically ordered the Aleutian strike force to break off and proceed toward Midway. But he was soon talked out of that decision by his staff, who suggested that even a small victory on American soil might help psychologically to offset the disaster at Midway. The northern force was ordered to proceed with its original mission. Before dawn on June 7, at least 1,200 Japanese invaders easily captured an American crew of ten manning a radio shack on Kiska. A similar-sized force invaded Attu, inhabited only by a small community of Aleuts and a sixty-year-old white teacher and his wife (the teacher was gunned down trying to flee).

Three more years of bloody fighting throughout the Pacific were to follow, but in five days the course of the war had changed. Would the result have been the same if two of Japan's fleet carriers had been at Midway rather than wrestling fog banks in the Aleutians? Hard to say, but this question was probably asked many times in the smoke-filled meeting rooms of the Japanese high command.

The Japanese quickly set about fortifying Attu and Kiska against invasion and moved seaplane bombers and fighters in to support their naval operations in the area. The Aleutian occupation was an ominous development in the eyes of the American public. With the fuzzy exception of some border disputes with Mexico, it was the first time enemy troops had taken U.S. soil in North America since the War of 1812.

Prior to the war, Washington legislators had been slow to recognize the significance of Alaska. Not until German troops stormed through Europe in 1940 did construction begin on new bases on mainland Alaska and at Kodiak and Dutch Harbor. With the impetus of Pearl Harbor, the

1,500-mile-long Alaska Military Highway from Dawson Creek, British Columbia, to Fairbanks, Alaska, was built by the Canadian and U.S governments in just eight months.

Standing alone on an open-air walkway on the starboard side of the *Safeguard*'s bridge, I examine the shoreline where the morning fog has joined the normal overcast to form a thick, low ceiling of clouds. Having reached Kiska Harbor during the wee hours of the morning, our ship is now moored in comparatively calm waters. Some crab pots on the dock are the only sign that anybody has been here since the Japanese departed. There are no trees in the Aleutians; severe rock outcrops contrast with the soft green, rich brown, and red of soil and tundra. Before the hillsides disappear into the mist I can see that they are heavily fortified with earthworks and gun emplacements and pockmarked with bomb craters.

Kiska was the second of the two islands to be retaken from the Japanese. In an effort to avoid the sort of hardships encountered on Attu (where 549 Allied soldiers were killed), the American and Canadian military spared no expense in hardware to soften Japanese resistance on Kiska. From May to August of 1943, U.S. Eleventh Air Force and Royal Canadian Air Force planes made numerous bombing runs from their new bases on Adak, Shemya, and Amchitka islands, dumping as much as 300,000 pounds of explosives in one day. The bombing runs were supplemented by bombardment from ships carrying guns with five-, eight-, and fourteen-inch bores, far larger than the .50-caliber machine guns that rest silent under the tarps on the *Safeguard*.

Briefly, the sun wins out in its struggle with the fog, and I glimpse a smoking volcano in the distance. I expect to see a prehistoric creature stick its head up from the shallows at any moment, but my reverie is broken by a sailor summoning me to the aft deck. The fantail is alive with activity, a break in the weather setting off a frenzy to get mobilized. Two 35-foot launches are being lowered to tow sonar gear and deploy shore parties, while rubber boats are readied for the diving operations. I am soon bouncing my way out to my first dive with Mike Eng. Our bright red dry suits, designed for cold-water diving operations, contrast wildly with the drab black boats and subdued tones of the Aleutian hillsides, especially since the

Michael Eng; National Park Service

Nearly fifty years after it was abandoned, a 75mm Japanese gun, left, overlooks Kiska Harbor. Below: A work party of Japanese soldiers in the Aleutians.

The Yomiuri Shimbun

overcast is already beginning to recover from its minor setback.

Cold-water diving makes one aware of parts of the anatomy usually taken for granted. Sinuses, for example, are like doughnut holes: empty spaces that are significant only because of their location. One is not likely to forget them, however, when diving in 36° water. They seem linked to the eyes, inner ear, and teeth through some kind of icy bond of pain. I grab the video camera handed down to me from the rubber dive boat and begin to come to terms with the cold water as I wait for my diving partner.

At times like this I usually mutter to myself, confiding to my regulator mouthpiece profane observations on the tooth-cracking cold, the slothful nature of my associates, and the general injustice of the human condition. As Mike and I begin our descent, my body begins to adjust to all the insults it has received, life regains its purpose, and my companions magically return to being competent and the salt of the earth.

We follow a white nylon buoy line that has been set by a navy team near one of our sonar contacts: a Japanese submarine lying in about 100 feet of water. Soon we are filming and sketching the remains of what archival documents tell us should be *RO 65,* a "Vickers Class" medium sub, noted in the Japanese records as an accidental loss. This conflicts with the U.S. Strategic Bombing Survey, which lists it as sunk by U.S. bombers out of Adak. We immediately note that whatever accident sank *RO 65,* it blew off the entire conning tower and left it (periscopes, snorkels, and all) several feet away from the upright, otherwise intact sub.

Northern Pacific anemones adorn the hull in splashes of white, red, and purple. Some wood decking survives, but most is in poor condition. We pass the torpedo tubes through which swimming bombs were helped on their way toward their targets by a burst of high-pressure air. The greatly superior quality of the Japanese torpedoes that emerged from these tubes became a major military scandal in the United States during the war. American sub skippers and their crews, who risked weeks of privation and danger waiting for the opportunity to launch torpedoes, often had to watch helplessly as their defective "fish" bounced off their targets.

Next we pass, mounted on the forward deck, the transducer for the upward-looking sonar, a device that was one of the inevitable technological turnabouts of war. Sonar was originally developed in 1918 as part of the tool kit of the surface forces that hunted submarines, but during World War II, the submariners adapted it to track their own prey from below. Suddenly, another feature of the sub absorbs all my interest: the hatch on top where torpedoes would have been loaded aboard the submarine. It would hardly be remarkable except that it is wide open. Like all openings into shipwrecks, it beckons.

I check my air-pressure gauge, which assures me that I still have more than two-thirds of my air supply remaining in the double eighty-cubic-foot tanks strapped to my back. Then I look over at Mike, my glance conveying much in the silent language of divers. He shrugs and nods. Translation: "Yeah, I see it; okay by me if you go for it." Mike has temporarily ab-

solved me of my responsibility to be an attentive buddy.

I extend the video light in my right hand down the slanting shaftway. I see no entanglements that can't be negotiated, so I pull myself down headfirst with my free hand. My movement stirs a light flurry of the silt that collects in shipwrecks, while my tanks scrape noisily against the edge of the hatchway. With a dull clank, I settle in a sitting position on a smooth, slanted surface, apparently the ramp down which the torpedoes were slid. The beam of my light is mesmerizing in the clear void.

I see some wiring covered in shiny insulation, to which silt doesn't seem to adhere. There are arrays of circuit breakers, electrical switches, and valves—the function of which are a mystery to me. Small signs on the panels may be in English, although I can't quite make them out. Like many other pieces of Japanese military hardware, this submarine was modeled after prototypes originally manufactured in the British Isles.

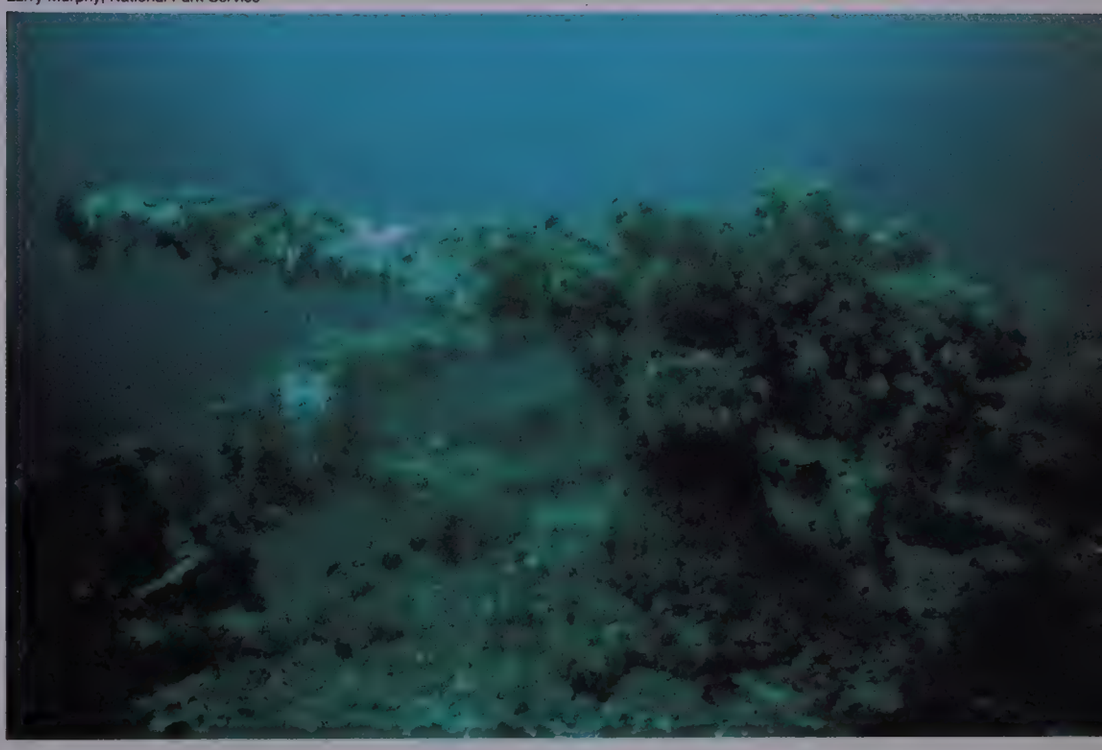
I know my movements, no matter how careful—even the air bubbles escaping from my regulator—will disturb the sediment and mar the crystal-clear water. Quickly I extend my hand back through the hatch where Mike is already handing down one of our small video cameras. Leaning forward, I start to record with one hand whatever is caught by the beam of the light held in my other hand. I slide forward over the ramp I am straddling to see if I can find and film a torpedo. As the camera and my eyes pan down slowly, following the light beam, they simultaneously take in an important fact: I am not straddling a ramp but am astride a torpedo, warhead in place. This makes for exciting video; luckily there is no sound track to record the muffled exclamations from my regulator mouthpiece.

I have been around a lot of munitions underwater, but, no ordnance expert, I am a firm believer in the no-touch rule. My Navy Explosive Ordnance Disposal compadres say most of it is harmless, but the stuff that isn't will turn you into red soup very quickly. I gingerly extricate my legs from around the lethal tube and take my leave of the compartment. Mike reaches down for the camera and light, and I am soon back on the sub's deck. Further examination reveals that the sub has a heavy chain stretched underneath the stern at the propellers. A navy salvage diver later explains that this is a common

Michael Eng; National Park Service

Abandoned on Kiska, a midget sub, left, bears a large scar from an explosive charge set by the retreating Japanese forces. Below: The Nissan Maru *lies at the bottom of Kiska Harbor, its bow gun still in place.*

Larry Murphy; National Park Service



ep in the procedure to salvage a submae. Seems plausible, but raises the quesn of who the would-be salvors were: panese or American?

A rush of bubbles and surface sounds d I find myself bobbing in the water in ont of our black rubber boat. The navy vemaster is querying me with a hand gnal to find out if I am okay, index finger d thumb curled to form a circle, the ner three fingers pointing skyward. My nds are too full of cameras and other cording paraphernalia to return the sigl, so I satisfy him by nodding vigorously. hile the support team helps Mike into e boat, I do a slow pirouette in the water d scan the brooding landscape.

The remains of hearths and stone tools an island off Umnak show that the first man invaders of the Aleutians arrived at least 8,000 years ago. By 4,500 years ago, the Aleuts had emerged as an identifiable people skilled at utilizing local marine resources. Then, in the mid-eighteenth century came the Russian explorers, sealers, and fur traders (*see* "Russia's American Adventure," *Natural History,* December 1989). As a result of disease and exploitation, the Aleut population plummeted from an estimated 12,000 to just 1,500 in 1825. The sale of Alaska to the United States in 1867 brought in a new horde of interlopers.

The Aleuts were themselves latecomers in the eyes of the otters, seals, birds, and other inhabitants of an archipelago left blessedly undisturbed by human intrusion for all the preceding millennia. The marvelous sea cows, already under pressure from Aleut subsistence hunters, barely made it a generation after the coming of the Russians, their passing into oblivion recorded by naturalist Georg Steller. This displacement of one species by another, or one race or nationality by another, is something we have come to accept as the natural course of events.

On our last day, Larry and I opt to join the land crew on a walking survey around the harbor, where we witness the remains of Japanese occupation forces: artillery emplacements, flattened buildings, complex caves dug into hillsides with machine guns still lying in them, and even a complete water system, including a fire hydrant with Japanese characters. This uninhabited island that has no vehicles or trees still has the scars of roadbeds and the remains of wooden bridges. A midget sub abandoned in its pen on land shows signs of a hasty departure: at least one of the gaping wounds in its metal side came from charges deliberately set from within.

On Attu, retaken by U.S. forces after bloody fighting from May 11 to 30, 1943, the last of the Japanese soldiers held hand grenades to their chests and pulled the pins rather than suffer the dishonor of being captured. Five hundred young men soaked the tundra with their blood and body parts. The defenders of Kiska took a different tack. One may recall the peace slogan from the sixties, "What if they gave a war and nobody came?" The Japanese just weren't there, not one. On July 28, while a U.S. battle group headed north to intercept a series of radar blips that turned out to be an electromagnetic Aleutian fantasy, the Japanese defenders boarded destroyers that had slipped through the fog to take them home.

Kiska was retaken August 15 to 18. The

Cormorants populate a small island in Attu's Massacre Bay.
Wolfgang Kaehler

lack of enemy forces didn't prevent twenty-nine fatalities from accidents, booby traps, and "friendly fire" when American and Canadian troops stormed the island and confirmed the growing suspicion of their officers that there was no one there to fight. The U.S. destroyer *Abner Read* struck a mine in Kiska Harbor, carrying seventy-one men to the bottom in her stern.

As we make our way back to the launch that will take us to the *Safeguard,* I am intrigued by one of the bald eagles that began circling our little party as we bounced back down the last green slope of springy tundra. It settles on a surviving communications pole and stares down at us, wings outstretched as if, distracted by the scurrying humans below, it has forgotten to fold them. It finally pulls in its wings and solemnly turns its back.

Back on board the *Safeguard,* Larry and I have assumed the chill-inspired, hands-in-pocket, hunched-over position on the fantail. We discuss with Susan Morton and Mike Boylan our project goals and accomplishments. Mike, manager of this refuge area for the Fish and Wildlife Service, has a what'd-I-tell-you look on his face. He knows that we are overwhelmed by the scenic splendor and archeological richness of his remote island domain.

No, we're not finished here; we will return if we can. Places like Kiska are precious. The bleak landscape provides a backdrop for this old killing field that speaks against taking life in any form. Some of the residues of war have been declared "historic" and protected, others viewed as "junk" and cleaned up by the U.S. Army Corps of Engineers. We hope that on Kiska and Attu, tidiness will not override our link with the past.

But we have used up all our ship time on Kiska and haven't even had a chance to touch Attu. Perhaps the Navy can be persuaded to help us again; their cooperation in these investigations, dubbed Project Seamark, is crucial when the targets are so remote. A slow, deep rumble begins in the bowels of the *Safeguard* as the engines warm up for our departure. I look back to where we last stood on shore and wonder if that eagle will notice us leave. □

Triumph of the Closet Naturalist

by Joseph Kastner

In 1845 John James Audubon got into an argument with John Cassin at the Academy of Natural Sciences in Philadelphia. Audubon was sixty, world famous for his monumental *Birds of America*. Cassin was half his age, a businessman who had recently been named curator of ornithology at the Academy, a position that carried much prestige but no pay.

On the face of it, this seems like a huge mismatch: the renowned star of art and natural history versus a semipro upstart. The argument itself—over the naming of Harris' sparrow—was of little importance. But a century and a half later, Robert McCracken Peck, currently a fellow at the Academy, wisely uses the incident to preface the handsome, new facsimile edition of Cassin's best-known work, *Illustrations of the Birds of California, Texas, Oregon, British and Russian America,* which has been out of print since 1856.

ILLUSTRATIONS OF THE BIRDS OF CALIFORNIA, TEXAS, OREGON, BRITISH AND RUSSIAN AMERICA, by John Cassin, with an introduction by Robert McCracken Peck. *Summerlee Foundation of Dallas-Texas State Historical Association, $29.95; 298 pp., illus.*

The confrontation that spring afternoon signaled the end of a great era in American natural history—the romantic period when adventurous naturalists wandered through the wilderness searching for the natural marvels of the New World. Now the last of these men was being pushed, not too gently—"Audubon talked like a fool," said Cassin tartly—into the past and into the company of a bygone cast of characters: Mark Catesby, the English amateur, who in the early 1700s roamed the South, living with Indians (and once sleeping with a rattlesnake), bringing new species to science and a new natural style to art; John Bartram, the self-taught Quaker farmer whom Linnaeus called "the greatest natural botanist in the world"; Alexander Wilson, the Scottish weaver who painted America's birds and then traveled all over the country peddling his books about them; Thomas Nuttall, the best field naturalist of his time, who had an instinct for nature but no sense of direction, and who was always getting lost on his transcontinental treks. And Audubon, the failed frontier storekeeper who became the finest painter of birds the world had ever seen.

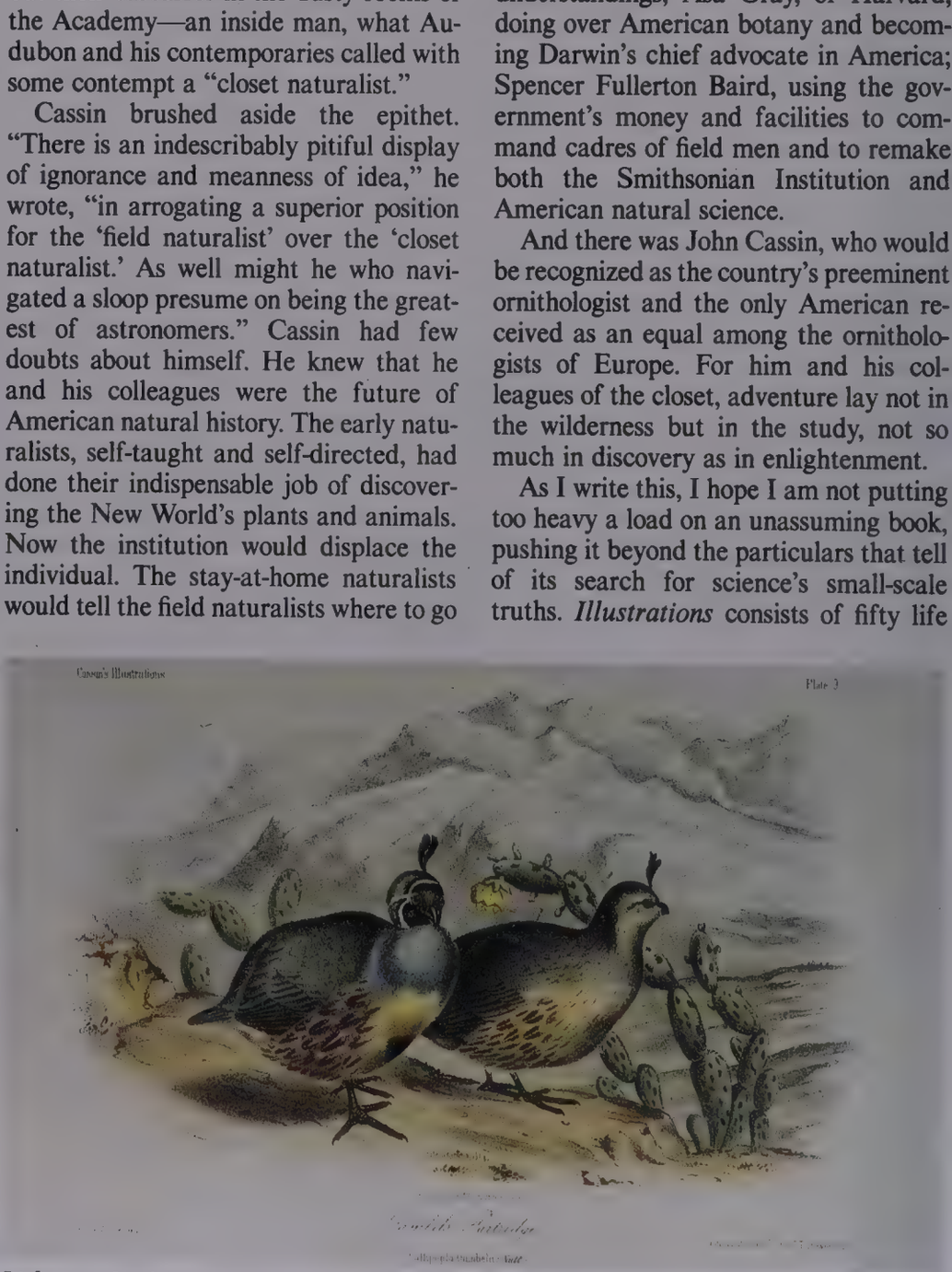
The man disputing Audubon—and his whole era—at the Academy hardly ever went birding beyond the environs of Philadelphia. John Cassin was a part-time scientist playing truant from his import-export business to observe, not living birds, but their carcasses in the dusty rooms of the Academy—an inside man, what Audubon and his contemporaries called with some contempt a "closet naturalist."

Cassin brushed aside the epithet. "There is an indescribably pitiful display of ignorance and meanness of idea," he wrote, "in arrogating a superior position for the 'field naturalist' over the 'closet naturalist.' As well might he who navigated a sloop presume on being the greatest of astronomers." Cassin had few doubts about himself. He knew that he and his colleagues were the future of American natural history. The early naturalists, self-taught and self-directed, had done their indispensable job of discovering the New World's plants and animals. Now the institution would displace the individual. The stay-at-home naturalists would tell the field naturalists where to go and what to send back so that they, with their book knowledge and laboratory expertise, could classify and fit everything into the revolutionary restructuring that Darwin was fomenting.

A company of wide-minded men, very much aware of their roles and responsibilities, would now run the natural sciences—such men as John Torrey, of Princeton and New York, who had worked to replace Linnaeus' taxonomy with one that could accommodate the new understandings; Asa Gray, of Harvard, doing over American botany and becoming Darwin's chief advocate in America; Spencer Fullerton Baird, using the government's money and facilities to command cadres of field men and to remake both the Smithsonian Institution and American natural science.

And there was John Cassin, who would be recognized as the country's preeminent ornithologist and the only American received as an equal among the ornithologists of Europe. For him and his colleagues of the closet, adventure lay not in the wilderness but in the study, not so much in discovery as in enlightenment.

As I write this, I hope I am not putting too heavy a load on an unassuming book, pushing it beyond the particulars that tell of its search for science's small-scale truths. *Illustrations* consists of fifty life



Lithograph of Gambel's partridge in Cassin's Illustrations
Texas State Historical Association

histories, each illustrated with a painting, plus a brief technical description. The writing is specific and careful. The paintings are accurate but not very convincing. The book was an important contribution to ornithology in its time but has been a neglected work of our natural sciences.

Cassin himself has been neglected, and Peck provides the first satisfactory, if necessarily too brief, biography. Born in 1813—just two weeks after Alexander Wilson died—Cassin grew up outside of Philadelphia and attended Westtown School, a Quaker institution that nurtured naturalists. Thomas Say, the first important American entomologist, studied there, as did John Kirk Townsend, the pioneering ornithologist of the American West, and Edward Drinker Cope, the zoologist and paleontologist.

In 1842 Cassin was elected curator of the Academy, and he soon turned that largely honorary position into a full-scale scientific job, putting the Academy's collections of bird skins in order and adding birds he coaxed from his business clients in other parts of the world. A bird bonanza fell into his lap when Edward Wilson, a wealthy Philadelphian, bought 25,000 birds from the Duke of Messina.

In 1852 Cassin began issuing sections of his *Illustrations,* finally putting them together as a book four years later. He contributed very few of his own observations to the book; a good many came from men who worked for the U.S. government either as naturalists assigned to various expeditions or as soldiers in the field.

This connection of government to natural history has been time-honored in America. Following President Jefferson's instructions, Lewis and Clark collected hundreds of plants and animals on their exploration of the West. President Jackson had Audubon to the White House for lunch (the toothless president had a mush of bread and milk; Audubon ate wild turkey that had been shot a few blocks from the White House) and assigned a navy ship to help the artist find Texas birds. Secretary of War Jefferson Davis assigned naturalists to the Army's topographical expeditions surveying railroad routes. Army officers in the West often collected birds and wrote about them.

Through the life histories in Cassin's volume, I became acquainted with the eloquence and wry humor of Col. George A. McCall (later inspector general of the U.S. Army), who reported on Gambel's partridge:

> I had halted to rest my jaded mules after a toilsome march. Figure to yourself a portion of this fair earth where for some hundreds of miles the whole crust seems to have been reduced to ashes by the action of internal fires; behold a vast plain of desolation glowing under the direct rays of a midsummer sun . . . a few stunted cottonwood trees. . . . Here it was that I first heard the plaintive voice of this bird as he strove to cheer his mate whilst occupied in the tedious task of incubation . . . kaa-wale, kaa-wale . . . something extremely plaintive in this simple love song.

Going through the book, I came upon naturalists I had encountered before. John Bell, for example, mentioned for his collection of California birds, once saved Audubon from being trampled by a wounded buffalo; shot the last known living Labrador duck; and in his New York shop, taught the rudiments of taxidermy to young Theodore Roosevelt. The section on the ferruginous hawk cites Adolphus Heermann, whose mother flirted with a younger Audubon when he taught her how to draw, and Richard Kern, who went west with Fremont and later died in the infamous Gunnison massacre.

Illustrations, important in its day for introducing dozens of species to nineteenth-century ornithology, reintroduces a fine scientist to our own times. The work is not—nor does it pretend to be—anything more than a detail in American natural history. But the history of our natural history consists too much of such details, seldom put into any intellectual and cultural context. Natural history has always held deep meanings for Americans. Through it they have tried to understand their country, and through it they have expressed a rich and unprejudiced patriotism. But only a few historians have dealt with such generalities—writers like A. Hunter Dupree, Raymond Phineas Stearns, Robert Henry Welker, Roderick Nash. Cassin's book has its own historical worth, but as a piece in an incomplete mosaic.

Getting out *Illustrations* was a struggle for Cassin. He had trouble finding good artists and a good printer for the book and never caught up with his subscribers. He took on other ornithological projects, collaborating on the 1858 *Catalogue of North American Birds,* the first modern work of American ornithology. Almost paranoid about letting anyone else handle his precious bird specimens, he worked over each one of them himself. Breathing in the arsenic dust used to preserve the specimens probably brought on his untimely death at fifty-five in 1869. He was remembered by future generations only by the sparrow, finch, and locust that have been named after him.

A brusque, sarcastic man, condescending toward other scientists ("our predecessors have not been well versed in the history of ornithology"), Cassin was still a loyal and warm friend and thoughtful about matters outside his science. In one strange passage, he writes that hawks "owe their existence to rapine and violence . . . [and] appear to personate one of the most momentous and mysterious of problems, the existence of evil in the world."

He denigrated fieldworkers: "Betake thyself not to the wilderness longer than forty days," he advised them. From time to time, in the stiff expositions of *Illustrations,* a different character peeks through, as when Cassin talks of his own field experiences—of watching the migrating hawks in the fall, checking out the birds at Cape May with his friend Stephen Fullerton Baird, and going out just to listen to a bird's song. As all birders do at some time or another, he tries to explain why birds so attracted him: "Delicacy of form, beauty of plumage, liveliness of disposition, elegance of motion" is the best he can do.

From John Cassin's own writings and Robert McCracken Peck's understanding text, we get glimpses of a man who knew the pleasures of nature but was kept in the closet by his own precepts.

Joseph Kastner, a former editor of Life, *and that magazine's first nature editor, has written on the history of natural history in* Species of Eternity *and* A World of Watchers.

A New African Ancestor

by John Van Couvering

"Hullo, here's a jaw." With these words, uttered fifteen minutes after pulling up to the foot of a mine dump in the Otavi highlands of northern Namibia, paleontologist Martin Pickford broke the unofficial world speed record for finding a new kind of prehuman fossil. It was June 4, 1991. Pickford, from the Institut de Paléontologie at the Musée National d'Histoire Naturelle in Paris, and three colleagues—Brigitte Senut of the same institute, team leader Glenn C. Conroy of the Department of Anthropology at Washington University, Saint Louis, and I—had just arrived at the inactive Berg Aukas vanadium mine for three weeks of prospecting in the local limestone caves for fossil-bearing deposits. We came as guests of Gold Fields Namibia, a subsidiary of the largest mining company in southern Africa. After the 300-mile drive from Windhoek, we were looking forward to cold beer, hot showers, and *braai* (barbecue) at the former mine manager's mansion. Unable to resist the last half-hour of daylight, however, we opted for a quick look at the huge dump behind the headquarters building to see if the mining operations had left behind any fossiliferous rocks from buried cave deposits.

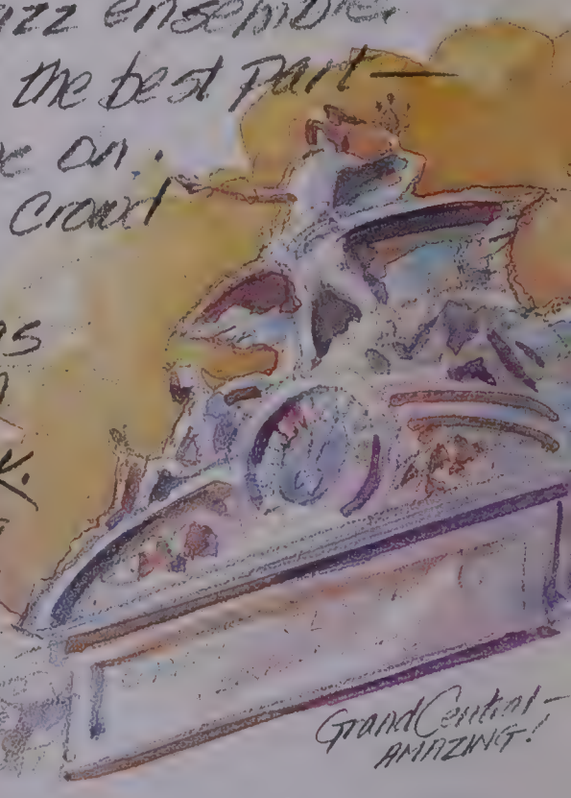
As we soon discovered, the Berg Aukas mine doesn't just intersect a cave, it *is* a cave. According to the company geologists we met the next morning, the mineral ores in Berg Aukas and the other big mines of the region occur entirely within ancient cave systems under the Otavi landscape. These caves and fissures are completely plugged with a natural concrete known as cave breccia, a solid mass of broken rock, dirt, and travertine, cemented by lime and crisscrossed by seams of black, yellow, and green ores. For sixty years, miners at Berg Aukas worked reexcavating one such petrified treasure cave, which slanted downward for more than half a mile. The water table under the Otavis at the edge of the Kalahari Desert is surprisingly high, and when mining was suspended in 1976 and the pumps were silenced, the tunnels flooded to within fifty feet of the surface. There is now no access to the tunnels; the only way to study what is left of the mine's interior is to climb over the rubble thrown out during excavation. Most of it is barren limestone from the walls of the ancient cave, but mixed in among these jagged blocks are bits of cave breccia that were too low-grade to go into the crushers.

Still partly encased in cave breccia, this Otavipithecus *jaw from Namibia is believed to be 13 million years old.*
Glenn C. Conroy and Tom Heine

The geologists explained that the presence of the vanadium, copper, lead, and zinc ores was the result of mineral-rich fluids seeping upward through the groundwater that saturated the cave deposits, gradually cementing and hardening them like glue soaking into a sponge. Later, when we studied the fossil evidence, we concluded that the caves had been open several times, probably when the lime-rich groundwater levels were low and the cave deposits were attacked by fresh surface water. Bats and owls roosted inside, leaving their remains and garbage, such as the pellets of rodent bones and teeth that owls regurgitate. These were later mixed with bones and dirt washed in by the rains, until the groundwater rose again and the cementing process resumed.

When Pickford spotted the jaw, it was enclosed in a fist-sized chunk of reddish yellow, porous material resembling coarse firebrick, which he had picked up from the rubble heap. All that could be seen of the fossil itself was a curved bit of yellowish bone with a damaged chin and the sides of three molar teeth, chocolate brown with the patina of ages and gleaming like cabochons in the dusk. The first clue had come a few minutes earlier, as the team examined a similar chunk found half-buried amid the shrapnel of dynamited limestone. Its uneven bricky texture gave it away as cave breccia; better yet,

After the show, we just headed down Broadway and fell into this charming cappuccino place. We were both still full from dinner, but we couldn't resist. Cozy little booths... A jazz ensemble. What a find. Oh, the best part— they had this singer come on. She was great. She had the whole crowd singing. Then, she passed the mic around and we all sang solos. It was hysterical. We stayed till 1:45 in the morning — and walked back. There was this guy selling paintings a few blocks from the hotel... and wouldn't you know, after 5 mos. of searching for something for the kitchen wall, we found it in 2 minutes. You should've seen us. I don't know what was bigger — the painting or the grins on our faces. And all I kept thinking was



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Latin American history and cultural traditions, which developed from European, African, and indigenous roots, will be highlighted by lecture-demonstrations, traditional and contemporary dance and music performances, and films. For a full schedule of events, call (212) 769-5315.

Somos Boricuas! We Are Puerto Ricans!

Puerto Rican music is the focus of the *Somos Boricuas!* celebration. In a series of performances, workshops, lecture-demonstrations, and panel discussions, artists from Puerto Rico, as well as from Philadelphia and New York City, will compare musical traditions that have developed in Puerto Rican communities. For information about activities, call (212) 769-5315.

Sunspots and Earth's Climate

Studies of sunspot activity over the last several centuries may help scientists understand global climate. On Tuesday, June 2, at 7:30 P.M. in the Sky Theater, Sallie Baliunas, of the Harvard-Smithsonian Center for Astrophysics, will present an illustrated talk, "Changes in the Sun's Energy Output and Global Climate Change." The lecture is the first in a three-part series presented by the Hayden Planetarium in conjunction with the Museum's exhibition "Global Warming: Understanding the Forecast." Tickets are $8 ($6 for members). For information about tickets, upcoming lectures, and Planetarium show times, call (212) 769-5900.

Klezmer

Instrumental Yiddish folk music, or *klezmer,* was played by traveling bands in Eastern Europe for hundreds of years. A new generation of *klezmer* musicians—many with jazz and bluegrass backgrounds—will perform in the Main Auditorium on Wednesday, June 3, at 7:00 P.M. Tickets are $20 ($12 for members). For additional information, call (212) 769-5606.

Identification Day

On Saturday, June 20, from 1:00 to 4:30 P.M. in the Hall of Ocean Life, staff scientists will be on hand to identify, analyze, and classify artifacts and natural objects (no gemstones, please) for the public. Also on display will be selected specimens from the Museum's collections. Experts from New York City's Department of Environmental Protection will test water samples and answer questions. For additional information, call (212) 769-5305.

Global Warming

"Global Warming: Understanding the Forecast," an exhibition jointly produced by the American Museum of Natural History and the Environmental Defense Fund, will run through January 19, 1993, in Gallery 3. A refrigerated core of ancient Greenland ice and a 2,000-year-old Tasmanian tree section will be among the displays showing past climatic changes, while computer models and multimedia exhibits will project new developments in global climate and show possible consequences for humans, plants, and animals. "Explainers" will be available each day from 1:00 to 5:00 P.M. to answer visitors' questions.

On the weekends of June 20 and 21 and July 11 and 12, science demonstrations in the Blum Lecture Room (on the first floor) will simulate various aspects of climate change, including how greenhouse gases trap heat.

A day-long film series, "The World of the Future: Science Fiction Films on the Environment," will be presented in the Kaufmann Theater on Saturday, June 27, from 11:00 A.M. to 5:00 P.M. For information, call (212) 769-5305.

Two day-long field trips will explore the computer simulations and predictive climate models that scientists use to monitor worldwide changes in the environment. Stuart R. Gaffin, a research scientist for the Climatic Change Program of the Environmental Defense Fund, will lead the trips on Saturday, June 6, and Wednesday, June 10. The cost is $150 (no discount for members). For details, call (212) 769-5310.

These events take place at the American Museum of Natural History, located on Central Park West at 79th Street in New York City. The Kaufmann Theater is located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

tiny jagged needles of white and yellow in the rock—the scattered and broken bones of bats and rodents—attested to the presence of fossils. The team was just fanning out to search for more breccia blocks when Pickford reached down for the undistinguished lump at his feet.

Discussions around the barbecue that cool winter's evening were very animated. Although the specimen was clearly from an anthropoid about half the size of a grown human, not enough could be seen to identify it further. There were empty sockets for a row of small front teeth and a broken-off root where a very large canine, or eyetooth, had been. The molars, although well preserved, were only partly visible; in particular, the all-important crowns were buried in the matrix. The tusklike canine ruled out the possibility that the specimen was an *Australopithecus,* the group directly ancestral to humans, known primarily from Makapansgat, Taung, Sterkfontein, and other caves in southern Africa in deposits between 4 and 2 million years old. Conroy, who had come to the Otavis hoping to find more australopithecine caves, cautiously, or perhaps pessimistically, voted for a baboon. I voted for chimpanzee, although it would have been the first fossil of its kind. Pickford voted for the most unlikely of all: *Kenyapithecus,* the African dryopithecine. Baboons and chimpanzees, as modern genera, go back no more than 5 million years. Dryopithecines, on the other hand, date from the middle Miocene, 15 to 13 million years ago; their remains are known from Europe, Asia, and the Near East, as well as from Africa. They represent the last common ancestor leading to the great apes (chimps, gorillas, and orangutans) on the one hand, and the hominid line leading to australopithecines and humans on the other. Pickford's guess, however, was nothing if not informed; over the years he had discovered most of the known specimens of *Kenyapithecus.* Still, to find a cave deposit this old in the Otavi limestone was very unlikely, as Pickford admitted. Brigitte Senut, a specialist in hominid limb bones, refused to speculate without a long bone to sink her teeth into.

All the next day, the team clambered over the mine dump—a pile of jumbled and broken stones the size of the World Trade Center toppled on its side—and searched out dozens of fossiliferous breccia blocks, some of them packed with tiny bones, without finding remains of another large mammal of any kind. Frustrated and unwilling to wait longer for the identity of our prize, the team agreed to begin a gentle chemical cleaning. Setting the fossil in a soup bowl, we added several cups of

kitchen vinegar and left the mild acid to slowly break down the limy matrix and reveal the crown surface of the molars. Baboons, being monkeys, would have four-cusped molars, with the cusps in two pairs separated by a central valley. Chimpanzees and kenyapithecines, being hominoids, would have five-cusped molars, with the cusps in a pattern like the tips of one's fingers bunched together.

Three days later, a hominoid had emerged. Whether chimp or kenyapithecine, it was the first ever found in southern Africa, and the find would be important publicity for the fledgling nation of Namibia, just one year after it had won independence from the Union of South Africa. Our fax to our hosts in Windhoek about the find had already started the publicity mills churning, and we knew we would be expected to answer all kinds of questions about the new fossil. Of course the first question we wanted answered was the age of the specimen, so Pickford and Senut took the residue from the vinegar bath back to France to be examined by Pierre Mein, an expert on fossil rodents. Under the microscope, Mein found among the sand grains many tiny teeth that could be identified as those of bats, shrews, elephant shrews, and six different species of extinct rodents whose age was known from other deposits.

Only a week later, we were somewhat dazed to find ourselves billed as "fossil man" discoverers at a government-organized press conference held in the mansion of Namibian president Sam Nujoma, in Windhoek. On the morning of that event, just before we were to go before the cameras, Conroy and I received a fax with the news we had not dared expect: the extinct rodents confirmed that the breccia deposit was of middle Miocene age, probably 13 million years old. The hominoid specimen was therefore a relative of *Kenyapithecus*—very far from Kenya, and very significant as a member of the almost unknown group that includes the common ancestor of apes and humans!

After the specimen was cleaned and analyzed at Conroy's laboratory at Washington University, the team concluded that this could be a wholly new type of dryopithecine, for which we coined the name *Otavipithecus,* ape from the Otavi highlands. In its specific characteristics, the existence of this unique southern proto-ape appears to indicate that the African dryopithecines were more abundant, diversified, and common than had been suspected. The problem remains, however, that there are no fossils representing the course of hominoid evolution in Africa during the almost 10 million years that followed the last known dryopithecines.

The advanced prehuman *Australopithecus* first appears in the middle Pliocene, 3.5 million years ago, and gorillas and chimpanzees have almost no fossil record whatever. The 8-million-year-wide chasm of ignorance in the late Miocene and early Pliocene is informally known as the hominoid gap because it is the unknown period during which the ancestral hominoid lineage must have evolved. Presumably, it was during this period that some populations of African dryopithecines differentiated into the three modern groups: orangutans; chimpanzees and gorillas; and humans.

This hominoid gap is doubly frustrating to paleontologists because the lack of fossil evidence has allowed molecular biologists to lay claim to this special bit of evolutionary terra incognita. Based on analyses of several different proteins, some have claimed that the biochemical difference between humans and their closest relatives, the chimpanzees, is so small that the split between the two must have happened no more than 4 to 6 million years ago. To most paleontologists, this seems to be an implausibly short time, because so many "human" characteristics are already highly developed in the 3.5-million-year-old australopithecines. Physical anthropologists have therefore begun to study the dryopithecines on the far side of the hominoid gap with renewed interest, to search for hints and clues as to what may have happened in Africa during the late Miocene and early Pliocene while the paleontological lights were out. The addition of *Otavipithecus* to the middle Miocene lineup, from a wholly different part of Africa, suggests that the mystery of the African dryopithecines may be even more complicated than anyone has suspected.

John Van Couvering is a geologist and editor of Micropaleontology Press at the American Museum.

Apes or Ancestors: A Hominoid Update

The discovery of the *Otavipithecus* jaw is the latest in a spate of middle Miocene dryopithecine finds from different parts of Africa, the Middle East, and the Mediterranean. Many of the new specimens, however, have not yet been written up or even identified. For scientists, this is a frustrating state of affairs, for it is difficult to borrow specimens or casts, let alone visit all the fossil collections around the world. To pool these recent discoveries of early hominoid fossils, the American Museum of Natural History, together with the Wenner-Gren and L. S. B. Leakey foundations, sponsored a gathering of paleontologists and their finds at the Museum. Twenty leading scholars were invited to bring their specimens and casts to New York for an unprecedented one-day "show and tell" workshop on March 28, just before *Otavipithecus* was to go into its temporary exhibit case. Intense discussions across a long table covered with trays of fossils lasted into the evening, during which the scientists had the opportunity to trade information and discuss interpretations of the evidence. Here is a capsule summary of the highlights.

• Meave Leakey, of the Kenya National Museum, announced that the genus *Xenopithecus,* or "strange ape," which had always been problematical because its characters seemed unlike those of other middle Miocene hominoids, has been redated. New geological studies of the fossil beds west of Lake Turkana now place it squarely in the upper Oligocene, 28 million years ago. This creature, therefore, is at least 5 million years older than any other known hominoid.

• Louis deBonis, of Poitiers University (France), displayed a new skull, with complete cranium and jaw, of *Ouranopithecus,* a large hominoid from 10-million-year-old beds in northern Greece. Although some fragments of the teeth and face had previously appeared to link this genus to ancestral orangutans, deBonis now believes the more complete specimen shows hominid affinities. It is thus a new candidate for oldest true hominid, but its place in the lineage remains enigmatic.

• The most baffling specimen was provided by Elwyn Simons of Duke University, one of the founders of middle Miocene paleoanthropology, who discovered a hominoid arm bone while prospecting long-neglected Miocene fossil beds at Moghara, in northwestern Egypt. This black, mineralized humerus appears to belong to an unknown arboreal hominoid, unlike others from this time period.

• The hominoid gap became slightly narrower with the report of new potassium-argon dating in Kenya that expands the time range of the best-known African dryopithecine, *Kenyapithecus,* to as recent as 12 million years ago. Also, after looking over the material, participants clearly favored the view that the African and European dryopithecines were more closely related to hominid origins than to the origin of the orangutans. *Otavipithecus* seems to share more characters with these non-Asian fossil primates than with any other.

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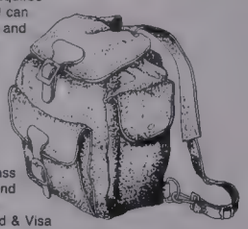

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Got a Second?

by Gail S. Cleere

Time is that odd fourth dimension we curse, bless, take for granted, and complain we never have enough of. We wear it on our wrists and hang it on the kitchen wall. It regulates our lives. In the greater sense, of course, it is the passage of the seasons, years, lifetimes, planets, stars, and galaxies—an endless transition between what was and what will be. How wonderful, then, to apparently add a moment more when it is needed, as we will on June 30. By international agreement, a leap second will be added at the end of the month to keep our clocks closely matched to mean solar time, marked by the rotation of the earth.

People have traditionally set clocks by marking the passage of the sun and the stars across the sky—in effect, measuring the time of one rotation of the earth on its axis. The earth, though, is not perfect; its spin is gradually slowing, but sometimes it speeds up, making it irregular in a way that we cannot predict. The sources of these irregularities in the earth's rotation are still not completely understood. Tidal friction caused by the gravitational attraction of the sun and moon, and the sloshing of the earth's fluid core, seem to play the largest role; atmospheric conditions and prevailing winds may account for smaller, short-term variations. The present day's length is about an hour and a quarter longer than a day in the age of the dinosaurs. As our clocks and our methods of observing distant astronomical objects improved, the discrepancy between the clocks and the earth's rotation became apparent. Our clocks are now the better timekeepers, and the two kinds of time occasionally drift apart.

Time in the United States is kept officially by the master clock at the U.S. Naval Observatory in Washington, D.C. It is actually based on the time kept by an ensemble of atomic clocks, which "tick" away totally independent of the earth and its rotation. At the same time, astronomers around the world make observations of quasars, the most distant objects in the universe. Since quasars show no inherent motion themselves because of their great distance, they serve as fixed reference points against which the rotation of the earth can be measured with incredible accuracy. When quasar observations are compared with the clocks, irregularities in the earth's rotation show up.

Any change in the clock is momentous news in the world of navigation, where time is distance. The earth's rotation is good only to within a thousandth of a second. Today's atomic clocks are good to within a billionth of a second per day—and getting better—a feat of measurement equivalent to figuring the distance to the sun to within a half inch. In celestial navigation, an error of one second will throw a ship crossing an ocean off course by a quarter of a mile. The difference between atomic clock time and solar time should not exceed nine-tenths of a second. Leap seconds are inserted now and then to maintain this level of agreement, as will happen at midnight on June 30.

The Planets in June:

Mercury is visible from midmonth, low on the west-northwest horizon just after sunset. During the week of the 14th, look for the planet just below Gemini's twin stars, Castor and Pollux.

Venus is essentially invisible all month because of its proximity to the sun. It reaches superior conjunction on the 13th, directly behind the sun as seen from the earth's perspective, and then enters the evening sky.

Mars is well above the eastern horizon by sunrise, amid the stars of Pisces (rather faint) and Aries. On the 26th, the old crescent moon is just a few degrees left of the ruddy planet.

Jupiter is in Leo, high in the southwest

as the sky grows dark. The planet moves slowly to the east below the bright stars Regulus and Denebola. On the evening of the 6th, the waxing moon (nearly first quarter) forms a triangle with Regulus and Jupiter.

Saturn rises about midnight and by dawn is nearly halfway up the southern sky. On the night of the 19th–20th, the waning gibbous moon passes just above the ringed planet.

Uranus and **Neptune** are the two blue-green worlds that can be seen with binoculars just east of the teapot-shaped constellation, Sagittarius, rising one and a half hours after sunset. Consult a detailed sky chart in one of the popular astronomy magazines for the exact location of these planets. On the 17th, observers with small telescopes in eastern North America can watch the moon pass in front of Neptune about midnight.

The **Moon** reaches first quarter on the 7th at 4:47 P.M., EDT; is full on the 15th at 12:50 A.M., EDT; reaches last quarter on the 23d at 4:11 A.M., EDT; and is new on the 30th at 8:18 A.M., EDT. A partial lunar eclipse, obscuring the upper two-thirds of the full moon, will be visible on the night of the 14th–15th. The moon will be in the dark part of the earth's shadow (the umbra) between 11:27 P.M. and 2:27 A.M., EDT, in the southern part of the sky as seen from the East Coast.

The **Sun** reaches the summer solstice on the 20th at 11:14 P.M., EDT, when it shines directly above the Tropic of Cancer, bringing the longest day of the year to the Northern Hemisphere. On the 30th, a total solar eclipse is visible in the South Atlantic.

Gail S. Cleere writes on popular astronomy and is a founding member of the International Dark Sky Association, an organization dedicated to preserving the skies for astronomy.

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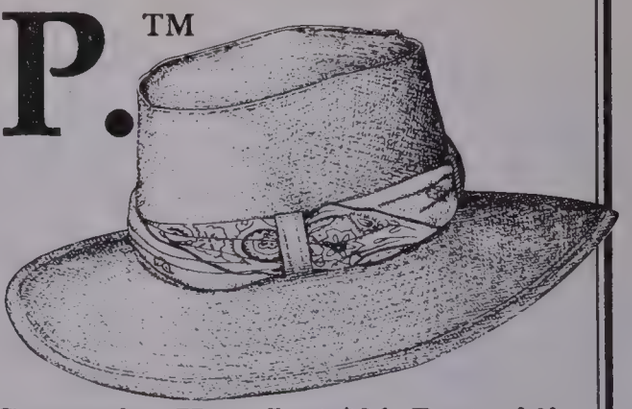

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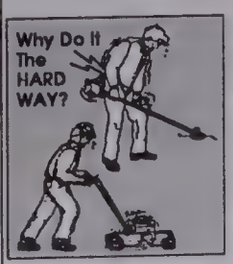

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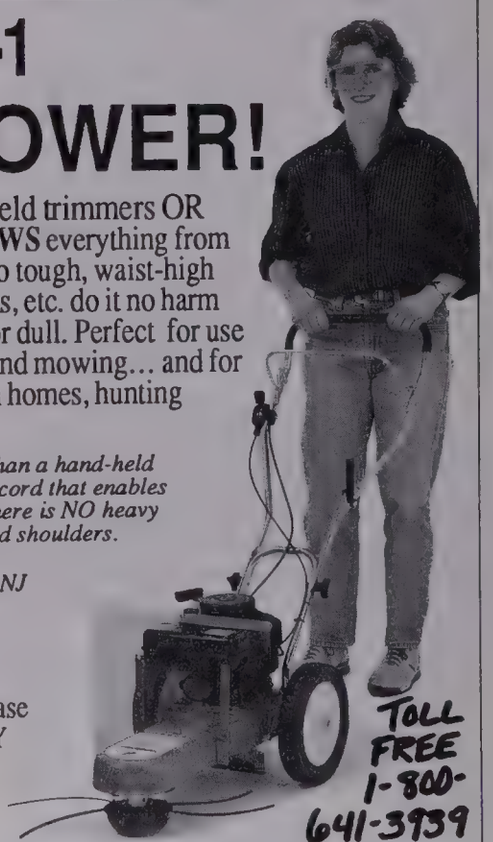

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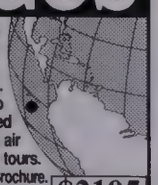

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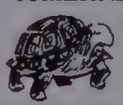

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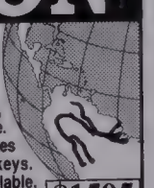

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This Is Quinoa

A little-known grain from the Andes has attracted the attention of the nutrition-conscious

by Raymond Sokolov

In this year of fussing over the 500th anniversary of Columbus's first landfall, much heat but little light has been generated. Nevertheless, it can be safely said that a few lessons have been learned by millions. *Quincentenary* is now a household word. And it will no longer get you any credit at cocktail parties if you announce that the tomato, the potato, and the green bean were unknown to Julius Caesar, Rabelais, and even Donatello, because these Old World culture heroes lived too soon to benefit from the enriching of the European larder that came after 1492.

This once esoteric notion about human ecohistory is now as unremarkable a cliché in our lives as the tomato, the potato, and the green bean. So the time has come to leave off exclaiming over the exotic origins of the familiar and to examine, with open minds and intrepid palates, foods—and food ideas—that did not get caught up by the Columbian exchange and did not get transplanted halfway around the world.

This project sounds simple and straightforward enough, but it actually involves a couple of basic conceptual difficulties. First, it's hard to talk about motion (of anything, not just foods) unless you know where you are. The physics of relativity turns on this question, and even the humble gastroethnographer has to think about his location in the universe before he can talk intelligently about his relation to the cuisines of the world and their ingredients.

If I were Chinese and living in Shanghai, I would have a very different attitude toward a baked potato than if I were a person of Irish heritage living in Boston. The Chinese in Shanghai would almost certainly regard a potato as a foreign mystery or at least as something that hadn't established itself in their normal food environment. Maybe they would know something about the importance of this Andean native plant to the history of Ireland, but they could not possibly have the profound sense of it, as would Irish Americans, whose ancestors migrated here because of the potato blight of the 1840s.

My own basic perspective is that of a native-born citizen with a semiactive Eastern European Jewish heritage. I try hard to consider food migration from the standpoint of people born and formed elsewhere or from a culturally neutral position, but in the end I think that it is more feasible and useful to construe the world from where one actually is than to try to adopt some universal outlook in which one pretends to observe the food of the world from outer space. So for some readers I will always be sounding naïve, or at least unredeemably North American, and also limited by my historical experience.

As a person of my time and place, I will always think of the mango as an exotic fruit I never encountered fresh until I was thirty years old. Consider how this sets me off from millions of people in India or Haiti, people who undoubtedly don't feel, as I do, that buckwheat groats (kasha) are quotidian fare.

Being who I am where I am, I am also more likely to have enlarged my diet to include foods I didn't know as a child. The United States has been much more welcoming to food imports than most other countries. Recently, the nouvelle cuisine has put a premium on novelty, which has also encouraged the food industry to take a chance on kiwis and Japanese buckwheat noodles. For their part, health food enthusiasts and new-age radicals embrace new foods because they question the diet they have inherited from Europe and their parents, and because they wish to show their sympathy for Third World cultures, something often easier to do at table in one's own house than in a more direct fashion. Finally, and most crucially, this country continues to welcome newcomers from abroad. Immigrants bring a hunger for familiar foods with them, and they soon find ways to appease that hunger, either by importing the food or by growing it here.

Every one of these factors has contributed to bringing us quinoa. *Chenopodium quinoa* is an annual, broad-leaved, dicotyledonous herb usually standing about three to six feet high. Leafy flower clusters (panicles) rise mostly from the top of the plant. The dry, seedlike fruit is about two millimeters in diameter and is enclosed in a hard, shiny, four-layered fruit wall (pericarp) containing bitter saponin. Quinoa seeds are usually flat and pale yellow and can be steamed, ground into flour, or fermented to make a mildly intoxicating beverage. Quinoa leaves are highly edible and are often used for livestock feed.

I acquired all this knowledge and much else from a publication of the National Research Council, *Lost Crops of the Incas: Little-known Plants of the Andes with Promise for Worldwide Cultivation* (National Academy Press, 1989). This learned study surveys thirty-one plants (or

A Chipaya woman of the Bolivian altiplano winnows quinoa.

Photographs by Loren McIntyre

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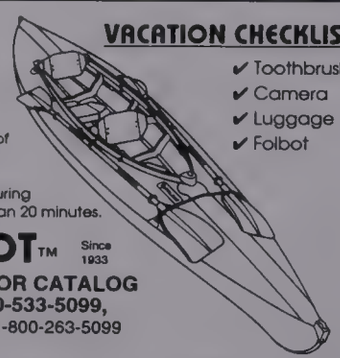

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plant types), ranging from the achira, a starchy tuber related to the ornamental canna lily, to the popping beans called *nuñas*.

Some of these tropical highland flora have already established themselves in large-scale cultivation and don't really belong in a book on "lost" plants. Passion fruits, tamarillo, and cherimoya are now available in U.S. markets as specialty items, and they are routine in many parts of tropical America. Even exotics like oca (another tuber) and tarwi (a legume) are not endangered species or even obscure on their native South American ground.

Perhaps it would have been better to call this extremely interesting book a survey of useful cultivated plants from the Andes that should be better known to the rest of the world. Quinoa is, happily, well on its way.

You will find it easily in health food stores in the United States. The twelve-ounce box of Ancient Harvest brand quinoa I bought sold for an impressive $3.19 (the equivalent of $4.25 a pound) and contained quinoa grain imported from Bolivia and Peru. The packaging was pure California, with color graphics, recipes, and some self-contradicting nutritional data. The recycled paper box announced that quinoa is the highest in protein of the

Basic Recipe for Quinoa

1 cup quinoa

1. To remove the sticky, bitter, soapy saponin that may still be present on the surface of quinoa, put the quinoa in a blender or processor with 2 cups of water. Turn the motor on and off briefly a couple of times. If the water turns cloudy, drain through a fine-mesh strainer and repeat until the water remains clear. This can also be accomplished manually, by rubbing the grains in a bowl full of water.
2. Bring 2 cups of water to a boil in a medium saucepan. Add the quinoa and cook over medium heat, covered, for about 12 minutes or until the water has been absorbed. Alternatively, combine the quinoa with the water and bring to a boil. Let cook for 2 minutes, then let stand, covered, for 30 minutes or until the water has been absorbed.

Yield: 4 cups

Ch'aqe de Quinua
Thick Quinoa Vegetable Stew

(Adapted from Nelly de Jordan's *Nuestras Comidas*, Cochabamba, Bolivia, 1962)

8 cups meat stock
1 pound stewing lamb, cut into 1-inch cubes
½ cup finely chopped onion
½ teaspoon ground cumin
½ teaspoon ground oregano
½ teaspoon ground black pepper
1 tablespoon cayenne pepper
1½ cups quinoa, thoroughly rinsed
½ cup peeled and skinned fava beans
½ cup peas
8 small potatoes (as a substitute for the variety called imilla *in Bolivia, which holds its shape during cooking, use Yukon gold)*
1 tablespoon salt or to taste
1 tablespoon finely chopped parsley

1. Bring the stock to a boil with the lamb. Add the onion, cumin, oregano, black pepper, and cayenne. Reduce heat and simmer for 15 minutes.
2. Stir in the quinoa and simmer until it swells and softens (about 12 minutes).
3. Add the favas, peas, potatoes, and salt. Cook for 20 minutes more or until the potatoes are soft, stirring from time to time to prevent burning.
4. Sprinkle with parsley and serve.

Yield: 8 servings

Note: The final result will inevitably be an approximation of the country stew de Jordan intended. For *ch'aqe*, she recommends a roughly processed form of quinoa not available here. The *imilla* potato, with its many eyes and gritty (*harinoso*) texture, is also not a practical choice. Perhaps it would make better culinary sense, given the cooking qualities of our favas and peas, to add them when the potatoes are almost done. In any case, I present this recipe for its "flavor" more than as a strict set of directions for reproducing the dish as one might find it in a Bolivian home.

Quinoa Pilaf

(Adapted from Maria Baez Kijac's *The Art of Cooking with Quinoa*, PM Publishing, 1991)

2 tablespoons vegetable oil
1–3 cloves garlic, minced
1 medium onion, chopped
1 cup quinoa, thoroughly rinsed
2 cups chicken stock or water

1. Heat the oil in a medium saucepan. Then sauté the garlic and onion for 2 minutes.
2. Add the quinoa and continue sautéing for another 5 minutes, stirring.
3. Add the chicken stock or water and bring to a boil. Cover, reduce heat, and simmer slowly for 12 minutes or until all liquid has been absorbed. Let stand, covered, for 5 minutes before serving.

Yield: 4 cups

world's grains. This claim is supported by figures printed on one side of the box but not those on the opposite side. One chart states that quinoa is 16.2 percent protein, while the next highest would be wheat with 14 percent. Another chart, however, tells the consumer that a 34 gram serving will contain 4.4 grams of protein, or by my calculation, only about 13 percent.

No doubt the discrepancy is a result of incongruent data sources. In any case, the appeal of quinoa is not so much for its marginal advantage in protein content over other grains, but for the quality of its protein.

You will recall that traditional nutritional science urges human beings to consume what has sometimes been referred to as the complete protein. This ideal protein would be composed of amino acids in amounts appropriate for human diet. Crudely, the complete protein's amino-acid spectrum coincides with the amino-acid spectrum of red meat. Vegetables do not match the profile, lacking the right amount of one essential amino acid or another. But defenders of vegetarian diets have traditionally countered by showing us that a judicious mix of vegetables will fill in the blanks, as it were. By mixing corn and beans, for example, the Aztecs are said to have overcome the scarcity of meat protein in their traditional diet.

The Chipaya husk quinoa by stamping on it.

Quinoa has attracted the interest of the nutritionally conscious vegetarian because its protein component has an amino-acid profile that very closely parallels the ideal protein standard sanctified by the Food and Agricultural Organization of the United Nations. As the authors of *Lost Crops* confirm, "Quinoa's protein is high in the essential amino acids lysine, methionine, and cystine, making it complementary to other grains (which are notably deficient in lysine), and to legumes such as beans (which are deficient in methionine and cystine)."

Yes, but how does it taste? Following the directions on the box, I cooked it "like rice," steaming it in twice its volume of water for about fifteen minutes. The grains fluffed up nicely, turned translucent. The taste was mild—all the bitter saponin on the surface of the grains must have been washed away by the manufacturer. And the texture was delicate and appealing.

Quinoa can be substituted for rice and most other grains in literally thousands of familiar recipes from non-Andean cultures. The inevitable process of creative adaptation is already happening, judging from the recipe for quinoa stuffed peppers with Mexican salsa on the Ancient Harvest box. This does not seem to me a sin against ethnographic or gastronomic principles. After all, some very traditional isolated villages in the Andes adopted European barley centuries ago and consume it, by preference, in greater quantity than they do quinoa. Younger villagers who can afford it prefer another nonnative crop, rice, to all other grains, according to M. J. Weismantel's *Food, Gender, and Poverty in the Ecuadorian Andes* (University of Pennsylvania Press, 1988).

As experimental restaurateurs and the general public learn to cook quinoa, the demand will surely grow. Even now, domestic U.S. production, in Colorado and other climatically suitable locations, is already beyond the pioneer stage. We can expect to see scientists improve new varieties of this member of the goosefoot genus (*Chenopodium*) to suit modern North American conditions. Will the eating quality and diversity of Andean quinoa strains be maintained? Or will space-age agronomy degrade the plant, as it has so often in earlier situations where an economically insignificant and horticulturally inconvenient plant fell afoul of Big Farming?

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

Ban the *Soleil*

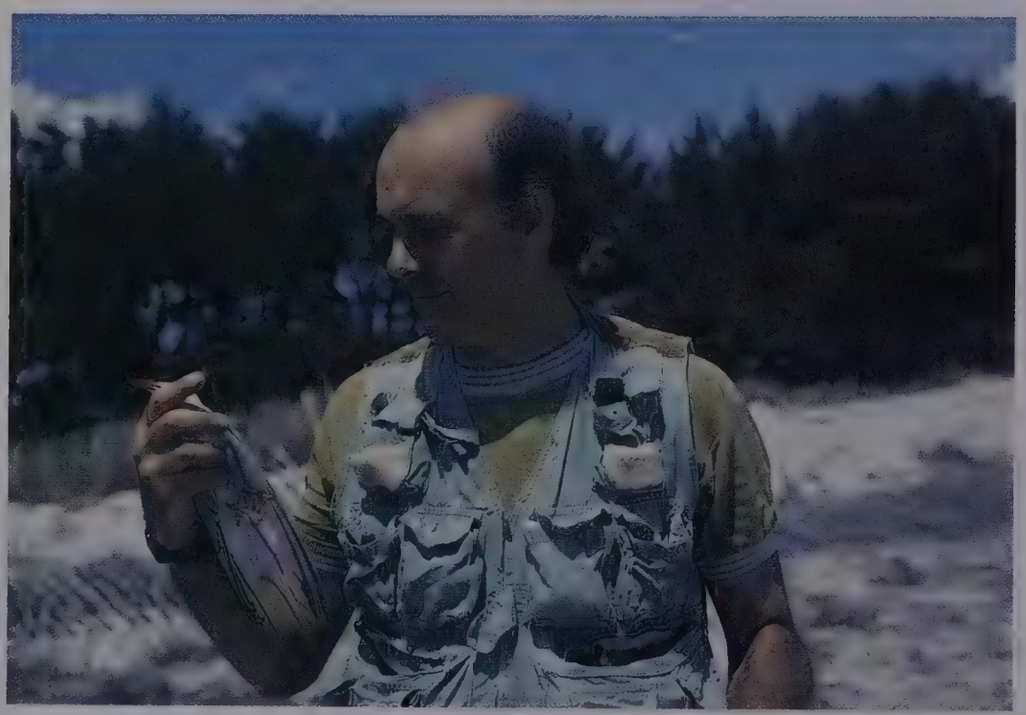
An African four-striped grass mouse nibbles new leaves as it balances atop a three-thorn bush in the Kalahari Gemsbok National Park in southern Africa. Although it usually dines on the green grass, roots, and seeds it finds on the ground, the mouse can skitter up fragile limbs to fetch tempting morsels dangling three feet overhead.

Most mice are nocturnal, but the grass mouse, with its chipmunklike stripes providing camouflage, scampers about in broad daylight. The fierce tropical sun is a formidable enemy, beating down throughout the mouse's range—the semidry bush and scrub habitats of eastern and southern Africa. This tiny creature has evolved adaptations to ultraviolet radiation, especially useful near the equator, where the sun's rays are most intense. Beneath its black and tawny fur, the mouse's melanin-pigmented skin is one shield; another is a melanin-pigmented tissue layer between the skull and skin that provides extra protection for the brain. At least three other types of diurnal African mouselike rodents are equipped with such "skullcaps" to protect them from the tropical sun. And according to Robert M. Timm, curator of mammals at the University of Kansas Museum of Natural History, white tent-making bats in the Central American tropics have similar adaptations in their skull tissue. The bats sleep during the day, but curled up with their heads exposed to the sun.

On cooler days, the four-striped grass mouse seems to enjoy basking in the sunshine—an activity many humans have been cautioned to avoid.—*Laura S. Carter*

Photograph by Charles G. Summers, Jr.

As a young teen-ager, **Joanna Burger** (page 44) began observing birds by following nesting killdeer hatched under squash plants on her parents' farm in upstate New York. In addition to studying avian nesting and coloniality, Burger is interested in birds as indicators of environmental quality; she serves as a U.S. representative to an international committee on environmental problems. She is currently a professor and director of the graduate program in ecology and evolution at Rutgers University in New Jersey. **Michael Gochfeld**, who has both a medical degree and a doctorate in environmental biology, is director of occupational health for the Robert Wood Johnson Medical School. His studies of colonial seabirds augment his current research on biomonitoring of human and



ecological exposure to such hazards as heavy metals. His interest in the social interactions of large flocks of nesting seabirds was piqued when he saw colonies of terns and other seabirds on Long Island. Subsequent observations raised questions about the birds' choice of particular nesting spots and the "significance of their impressive attacks on the human intruder, me." Burger and Gochfeld, who are married, have done fieldwork in Africa, Australia, and throughout the Americas. They share their home with a thirty-seven-year-old parrot named Tico. They have coauthored *The Black Skimmer: The Social Dynamics of a Colonial Species* (New York: Columbia University Press, 1990) and *The Common Tern: Breeding Biology and Social Behavior* (New York: Columbia University Press, 1991).

Wildlife photographer **Charles G. Summers, Jr.,** (page 76) thought he saw fruit hanging in three-thorn bushes in Africa's Kalahari Gemsbok National Park, until a warden told him he was seeing mice. Summers drove slowly toward the skittish creatures, shut off the car's engine, and coasted to a stop until he was only nine feet away. But he never got out of the car. "I had to take the pictures fast. Once they realized I was close, the mice generally scampered away." Summers gave up a career in mechanical engineering to photograph wildlife around the world. He is also a partner in a Colorado-based company that publishes computer software for photographers and photo libraries. For this month's "Natural Moment," he used a Nikon F4 camera with a 600mm lens and an extension tube.

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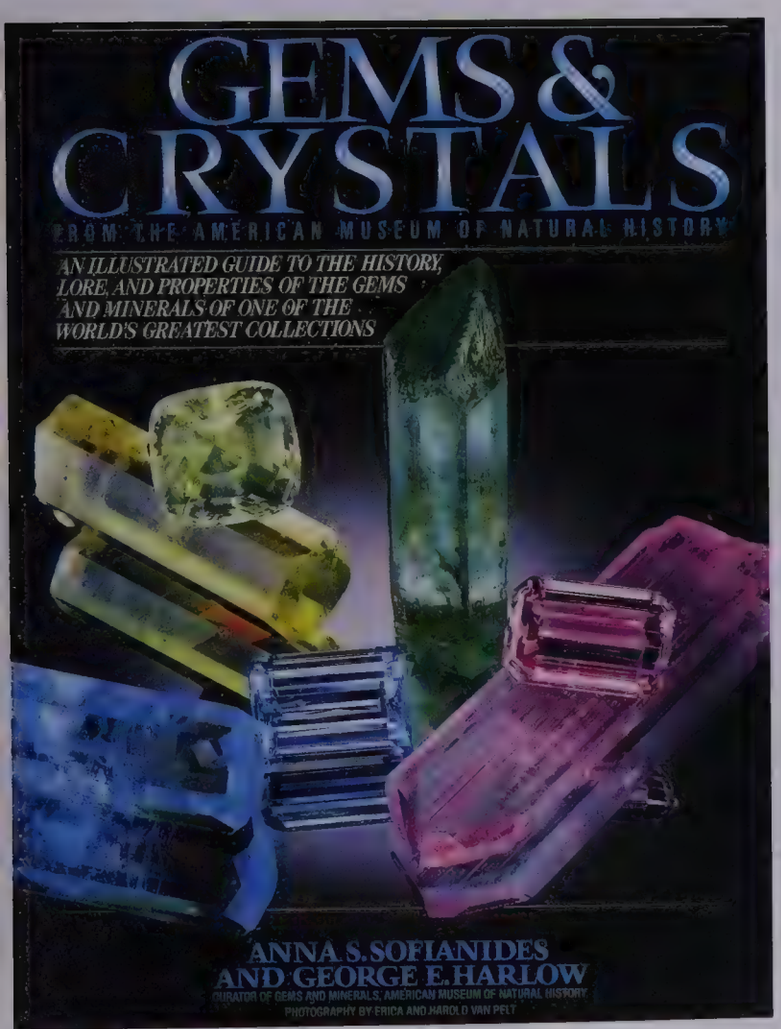
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JULY 1992

COVER: *An Amazon warrior adorns the rim of a 2,500-year-old bronze basin discovered in Campania, Italy. Equestrian and archery skills were prized in the eastern Mediterranean, the cradle of the ancient Olympics. Story on page 50. Photograph courtesy of the Robert Harding Picture Library.*

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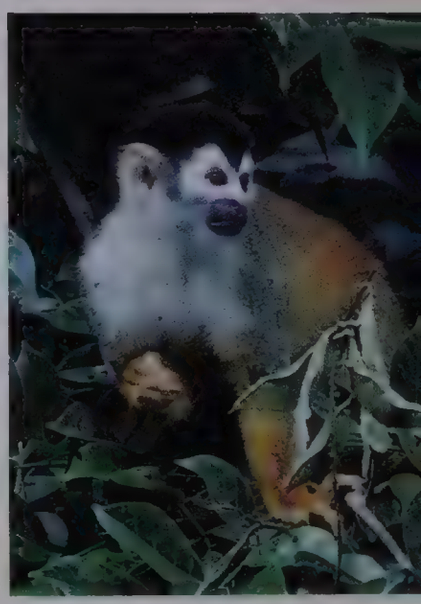

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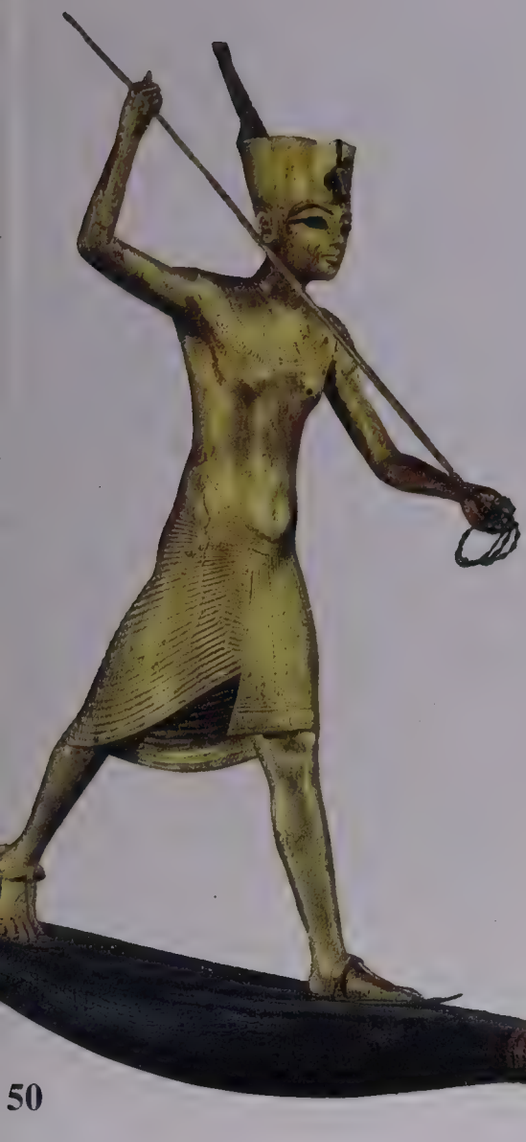

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NATURAL HISTORY (ISSN 0028-0712) is published monthly by the American Museum of Natural History, Central Park West at 79th Street, New York, N.Y. 10024. Subscriptions: $25.00 a year. In Canada and all other countries: $34.00 a year. Second-class postage paid at New York, N.Y., and at additional mailing offices. Copyright © 1992 by American Museum of Natural History. All rights reserved. No part of this periodical may be reproduced without written consent of Natural History. Send subscription orders and undeliverable copies to the address below. Membership and subscription information: Write to address below or call (800) 234-5252 if urgent. Postmaster: Send address changes to Natural History, Post Office Box 5000, Harlan, IA 51537-5000.

OVERHEATED ELEPHANTS

I do not know whether dinosaurs were endothermic or ectothermic, but Peter Dodson ("Letters," April 1992) is wrong to suggest that the elephant cooling system is taxed in full sunlight, based on the animal's physiology when sedated. The main drugs used for immobilizing noncarnivorous wildlife are Etorphine (M-99) and Carfentanil, which not only sedate an animal but also shut down its thermoregulating system. In Alaska, even during the winter at –20° F, care must be taken to prevent the death of moose and caribou during capture operations. If the animal is chased for long distances before it is injected with an immobilizing drug, the heat produced by the physical activity cannot be dissipated. Even small deer can die from heat stroke while under the influence of these drugs.

African elephants are not unique in this drug sensitivity. Having seen them run for long distances under the hot African sun and not finding them dead later, I seriously doubt that their vascular systems used for cooling are indeed taxed in full sunlight. The same is probably true of the great whales during their bouts of intense physical activity in tropical waters.

TIMOTHY OSBORN
Galena, Arkansas

LAMARCKIAN CHILD-REARING

Regarding Stephen Jay Gould's April 1992 essay, "Does the Stoneless Plum Instruct the Thinking Reed?": Burbank's two final steps in his human eugenics method are clearly Lamarckian, yet I'll confess a certain attraction to his recommendations for the raising of children. And as a further argument in support of these methods (snakes and mud pies, hayfields and huckleberries), I'll offer this justification: While human biological evolution is certainly operating according to Darwinian principles, our cultural evolution is more nearly Lamarckian. Culturally, people will tend to pass on what they've inherited, and if they've been fortunate enough to be raised with decency and consideration (instead of oppression and abuse), one hopes and supposes that they would be likely to provide their children with a similar environment.

CRAIG HOHM, M.D.
Penn Yan, New York

SUPER-DUPER OXYGEN

Perhaps all that superheavy oxygen up there in Greenland is causing the climate changes Wallace Broecker discusses in "Global Warming on Trial" (April 1992). Down here in Texas we only have the conventional stuff: eight to ten neutrons per eight-proton oxygen atom.

NICHOLAS E. PINGITORE, JR.
University of Texas
El Paso, Texas

Because of an editing error, the word *neutron* was substituted for *nucleon*. The mistake gave oxygen eight more neutrons than it really has. Our apologies to Dr. Broecker and the readers.—*Eds.*

POISONOUS OR NOT?

Nice piece by George Barron on "Jekyll-Hyde" mushrooms in the March 1992 issue. However, I was amused to find a shaggy *Pholiota* mushroom captioned as "poisonous." I believe this is *P. squarrosa*, which I have been collecting and eating for years and which is listed in Orson Miller's *Mushrooms of North America* as "edible/common." In fact, Miller says that there are no reports of toxins in the *Pholiota* genus and that most species are unqualified edibles.

JIM COLLINS
Brimfield, Massachusetts

GEORGE BARRON REPLIES:

In the original hard-cover version of Orson Miller's book, *P. squarrosa* was listed as "edible," but the listing of this, as well as of some other *Pholiota* species, was changed in later editions to "poisonous." The problem is that many people, like you, can eat and enjoy *Pholiota* mushrooms. Others suffer gastrointestinal distress. While the toxins are not life threatening, the public should be made aware that there is a chance of such upset.

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Ten Years on an Aspen Branch

For nesting broad-tailed hummingbirds, a certain limb held an attraction—and a curse

by William A. Calder

Our lives are too brief for us to learn all there is to know about the biosphere's complexity. Naturalists can only sample here and there—running transects up mountains, comparing plots in forests or meadows, censusing the life in a pond or a tree, or studying the biology of a single bird species. But can a single tree branch tell us much about life?

Each spring, broad-tailed hummingbirds begin their migration from Mexico to their summer home in the Colorado Rockies. For many years I too have migrated there, to observe their nesting cycle. The dramas played out over a decade on a particular aspen branch have given me a great appreciation for the odds against which these birds must struggle.

Broad-tailed hummingbirds often nest in quaking aspens, slender deciduous trees with smooth, gray-green bark. Individual trunks rise forty or more feet from a single base plant. Aspens cover most of a slope north of the former mining town of Gothic, Colorado. The slope's rocky debris, dumped by a melting glacier some 10,000 years ago, was gradually clothed by lichens, mosses, cinquefoil, aspen, and finally, a forest of spruce and fir. In the late 1800s, silver mining, logging, and fires left few of the trees standing. After the mines were abandoned early in the 1900s, another round of succession began. Aspens once again shield the slope, at least part of the year, from the cold night sky and intense sunlight. Pioneer trees, aspens thrive in sunshine. When higher branches or overtopping conifers intercept its sunlight, an aspen branch will drop its leaves and die in a natural pruning process.

After flying some 1,200 miles north from Mexico, the hummingbirds need six weeks—more than half the length of the subalpine summer—to build a nest, incubate two eggs, and raise the chicks. A second nest is feasible only if the first fails early in the season. Quality, not quantity, is what counts in hummingbird reproduction. At 9,500 feet in the Elk Mountains, the aspens leaf out in late May. The ensuing wildflower season, which provides nectar for the birds, is spectacular but brief. At first, the hummingbirds will settle for pussywillows and glacier lilies or fly back down the valley to hummingbird feeders, but they later rely on the flush of Nelson's larkspur, red columbine, scarlet gilia, Indian paintbrush, and Barbey's larkspur for sufficient energy to stay warm at night, for daytime flights, and for the demands of nesting.

A nest on the lowest intact branch of an aspen will give a hummingbird a good view, a clear flight path, and protection for her young. Male hummingbirds claim feeding territories in open meadows and willows where, from late May through June, they mate with females coming to feed but take no part in nesting. Thus, when the hen is away to feed, the nest is unguarded. While the smooth bark of the aspen trunk generally offers a poor grip for the claws of a hungry red squirrel or weasel, aerial attacks, from a sharp-shinned hawk, pygmy owl, Steller's jay, or gray jay, are more likely. The choice of where to build the nest is based not only on the branch itself but also on what hangs over it. A crooked deformity in the nest branch, a second, unusually close branch overhead, or proximity to part of a trunk bowed by a past ice storm are features that

A female broad-tailed hummingbird at her nest in a subalpine fir
Art Gingert

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This misshapen aspen branch attracted breeding hummingbirds almost every year for a decade. Projecting above the nest rim are the heads of two hatchlings.
Lorene Calder

provide shelter and make for an attractive nest site. Scarcely larger than a halved golf ball, the nest is painstakingly constructed of spider webs and plant down, decorated and camouflaged outside with paperlike bits of aspen bark held together with more strands of spider silk. By early June it will hold two pea-sized eggs, which each weigh one-seventh of the mother's weight, and in sixteen to nineteen days, two chicks.

By day, the "roof" formed by an upper branch or crook shields the nest and its contents from predators' eyes and from intense mountain sunshine. By night, the roof helps conserve heat. (Since the atmosphere is about a third thinner at this elevation than at sea level, the greenhouse effect is correspondingly diminished. Consequently, animals rapidly lose heat to the unobstructed mountain sky.) Without a roof, the tiny hen's warming ability would be overwhelmed by rain, sleet, or snow, even in summer, or her body heat would dissipate too readily into the chilly, occasionally subfreezing air. A hummingbird's image of a secure nest site takes into account her need to conserve heat—her 190-milligram brain stores an effective energy policy. Only when storms prevent her from feeding sufficiently during the day will she have to turn down her thermostat and go into a minihibernation state, apparent to observers from the accompanying lethargy or torpor (*see* "Energy Crisis of the Hummingbird," *Natural History,* May 1976).

Claims have been made for the same female bird returning to the same tree, bush, or branch for several years. These reports usually assume that the birds are long-lived and have a bond to "home," a phenomenon known as site fidelity, or philopatry. Do these presumptions hold up or do they simply indicate that all hummingbirds have a common nest-site image, an innate picture of the ideal spot for rearing young?

My colleagues and I, with the long-term support of the National Geographic Society, spent many summers trying to find out, among other things, which broad-tailed hummingbirds were nesting where. Because physical peculiarities that can be readily distinguished by an observer are rare in birds, and because feathers are replaced annually, the only way we have of knowing an individual bird from year to year is by its band number, and a band that fits above a tiny hummingbird foot is almost invisible to the field observer. However, small dabs of paint on the corner of a tail can be seen from below with binoculars, and this is how we mark and recognize our hummingbirds in Colorado. We capture hummingbirds at feeders, then weigh, band, mark, and release the birds. While bands last from year to year, the birds must be caught and painted anew each season for easy field identification. Chances are limited, however, for matching known birds with known nests. In a good year, about one in ten females evades capture for marking, and we find only one nest for every six females captured.

Thirty feet above ground and just west of the fork between old mine roads to Virginia Basin and Copper Creek is the low-

est unpruned branch on aspen 12-84. A subbranch crooked under the main branch forms a seemingly perfect nest site, and indeed, a hummingbird nested there each year from 1981 through 1984—our longest series up to that time for one site. Was it the same hen each year? Only in 1982 did the occupant manage to avoid being captured and painted for identification. In the other years, color codes, correlated with band numbers, indicated a turnover of three different birds. None of these attempts to nest succeeded. The females had flown 1,200 miles only to have their nests fail ten to seventeen days short of the time the chicks were to fledge. Perhaps a hawk, owl, or jay made the nest contents on this branch a favorite annual snack. Our checks were made through binoculars from a distance that does not inhibit the normal activity of a nesting hummingbird but does keep us from being able to see into the nest thirty feet above, so we were unable to determine exactly what mishaps had occurred.

A hummingbird hen is not likely to renest in a spot where she came to grief the previous summer. But a newcomer would not know the history of the branch, only that, physically, it meets the criteria for a good nest site. I was almost relieved when no bird nested on this seemingly cursed branch from 1985 through 1987.

After four years of tragedy and three of vacancy, the branch attracted another hummingbird in 1988. With other nests to keep track of, we were unable to document her every move, but our intermittent diary entries recorded her progress whenever we caught up with her.

May 28: An unbanded female comes to our feeder and feeds until she reaches a weight of one-eighth of an ounce. We weigh and band her and mark her tail with dabs of yellow and violet. (Hummingbirds are not little people, but we can call her Sue for convenience.)

June 3: Sue weighs a full sixth of an ounce after feeding, suggesting that she is carrying eggs under production.

June 8: Sue patiently incubates for twenty or more minutes at a time, oblivious to her branch's ominous history.

June 21: Sue perches on the side of the nest, with her tail propped, woodpecker fashion. Her eggs have hatched! Rapidly and repeatedly, she thrusts her head down into the nest cup and back up, like a little sewing machine, pumping food into chicks that are not visible from the ground.

July 9: Above the rim of the nest, a billed head and a tail are now visible side

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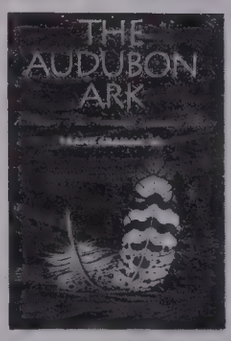

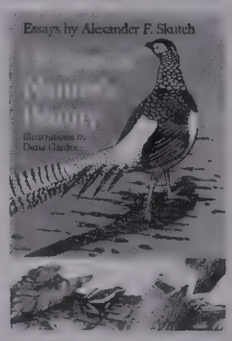

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by side—two chicks facing in opposite directions.

July 12: Chicks are sitting high, looking like real hummingbirds.

July 14: One chick perches on the edge of the nest, which has stretched from a cup into a platform. It preens and exercises its wings; this indicates self-awareness and growing freedom of movement.

July 15: At 7:16 A.M. both chicks are still on the flattened nest. At 9:05 just one chick is visible; Sue comes to feed it. A mule deer doe walks past, taking my attention from the scene overhead. When I look back to the nest, it is empty. Sue flies to some branches about ten feet away in an adjacent aspen, where both tiny chicks are preening. She feeds each and disappears. One of the chicks, then the other, ventures farther into the canopy of quaking aspen leaves.

The young birds had outlived confinement to the nest and had fledged. Had the curse on that branch run out? One scenario would be that the unknown predator had met with its own tragedy before the annual hummingbird raid. This year, it was the hummingbird chicks' turn to survive. Perhaps they would find their way back to the ancestral home in Mexico and live to return to their birthplace to breed next summer. We banded ninety-one juveniles by the summer's end and recaptured twelve of them the next year, although we had no way of knowing which nests they had come from.

Having broken the curse, would Sue try it again next year? When she failed to show up at the feeder trap for re-marking in 1989, I began to patrol the aspen woods, to no avail. On June 1, a female flew directly to the old nest. She inserted new material with vigorous thrusts, smoothing the exterior with the underside of her bill, rearing back and vibrating as her feet tamped in the bedding. Every two minutes or so, she made a trip for more material. However, this bird, color coded red-blue, was not Sue; we called her Rosie.

During one of Rosie's brief absences, another female came in and began snatching away the nesting material with her beak. On a second thieving visit, she was caught in the act and chased away by Rosie. Was the second bird the former owner, Sue? Had she arrived late, and was she perhaps trying to even the score by claiming some of the nest insulation, if not the site itself? Searching the woods below, where the thief had retreated, we found three other females building nests within ninety yards. They were all marked, but Sue was not among them.

We were away from Gothic at the end of June and on our return were unable to spot Rosie or any bird at the nest. By now, any surviving chicks should have been visible above the nest rim, although not scheduled to fledge for at least ten more days. The lip of the nest cup was somewhat tattered and not as high as it had been when we left. At some point, the fine material had been removed. In a rainstorm on July 23, Rosie did come to our cabin, preferring a quick sip at the feeder to flying through a wet flower patch for droplets of nectar. At least she had survived, and perhaps renested.

The next year, on June 7, an unidentified female began constructing a nest on the aspen branch. A week later, she had disappeared, and by June 16, the nest material was gone. Females expend considerable energy gathering the fine organic bits that are the makings of a nest, so recycling, salvage, or thievery of such material, for nesting elsewhere, is common.

That was the seventh nesting attempt in ten years, our longest record for any nest site. A different hummingbird nested each time, with the possible exception of 1982 and 1990, when the females were unmarked, so the branch configuration obviously fit the innate image of the ideal site. Not so obvious were the predatory-neighbor problems. How long does a frustrated mother carry the scars of such failure? Do the urgency of fattening herself up for migration and her instinct for self-survival dispel any grief, as the endocrine cycle shifts from a breeding to a traveling mode? Such questions go beyond scientific inquiry but nonetheless have come to mind during my summers in the Rockies.

The biological lesson of the aspen branch is the tenuous nature of hummingbird reproduction. Of seven round trips from Mexico, six nesting tries were in vain, unless some tenants of the branch moved elsewhere in time to succeed with a replacement nest. With odds like that, how have hummingbirds persisted? To maintain a stable population, the hens need only to replace themselves and their mates, averaging two offspring that then survive to breed successfully themselves. If only one in seven nestings accomplished that, the average reproductive life span would need to be seven years to insure the species' survival. Our oldest female broad-tailed hummingbird was last recaptured in Gothic when she was at least twelve years old, setting the North American record. However, parenthood is usually squeezed into a shorter span, averaging three years in this population.

A hummingbird's life is not an easy one of zipping from one flower to another. On average, a female broad-tail has just three years, three migrations, three chances to nest. And averages do not tell the full story. The hummingbird's choice of a nest site is a crucial mixture of parental skill and sheer luck against great odds.

William A. Calder, a professor of ecology and evolutionary biology at the University of Arizona, Tucson, does research at the Rocky Mountain Biological Laboratory in Gothic, Colorado.

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A Humongous Fungus Among Us

The discovery of an enormous underground organism raises some basic questions about individuality

by Stephen Jay Gould

When an animal achieves disembodied immortality by becoming a verb, human speakers usually honor its behavior: we hawk our wares, gull or buffalo our naïve competitors, hound our adversaries, and clam up in the face of adversity; we have also been known to man the barricades and kid around with our companions. But plants and other rooted creatures do not feature so great a range of overt actions, and our botanically based verbs therefore tout growth and appearance as sources of metaphor.

Consider the two most prominent examples, citing comparable phenomena but with such different meanings—for one usually expresses our joy and the other our fear. Art and prosperity "flower"; taxes and urban violence "mushroom." The burden of difference reflects an obvious source in our culture and legends. We love the bright flowers of "higher" plants, either radiant in the sunlight or jewellike in the quiet darkness of a forest. We loathe the spongy, fruiting bodies of "lowly" fungi, growing in dank dampness, sprouting in cancerous formlessness from rotting logs. (Even a colorful mushroom usually strikes us as sinister rather than lovely.) I well remember a common schoolyard taunt, often cruelly directed at unloved classmates: "There's a fungus among us"—a cry that always inspired the ritualistic retort: "Kill it before it multiplies."

Combine this image of uncontrolled and noxious fungal growth with our general fascination for superlatives—the biggest and most persistent in this case—and we can easily understand the flurry of press commentary that greeted a technical article by M. L. Smith, J. N. Bruhn, and J. P. Anderson in the April 2, 1992, issue of *Nature:* "The fungus *Armillaria bulbosa* is among the largest and oldest living organisms." On the same day, the *New York Times* reported the discovery in a front-page story with a more sprightly headline: "Thirty-Acre Fungus Called World's Largest Organism." [Editor's note: As this column was being prepared for press, the Associated Press reported the find of a larger fungus, an *Armillaria ostoyae,* covering about two and a half square miles in the state of Washington. Larger organisms probably will be found, but the discoveries will not change the point of this piece.]

We divide muticellular life into three great kingdoms: animals, plants, and fungi. How does this new *Armillaria* stack up against the champions of the other domains. Blue whales, by far the largest animals that ever lived (edging out both *Ultrasaurus* and *Supersaurus* from the world of dinosaurs), may reach 100 feet and as many tons. (Incidentally, since female whales exceed males in size, the largest individual animal of all time was undoubtedly female.) Sequoia trees are bigger by far, sometimes exceeding 1,000 tons (although mostly in nonliving wood), not to mention heights measured in hundreds of feet and years in thousands.

Armillaria bulbosa lives in and around tree roots in European and eastern North American mixed hardwood forests. Clones begin as a single fertilized spore and then spread out by vegetative growth. The basic unit of spread is a hypha, or threadlike filament that forms the structural unit of growth in many fungi. In *Armillaria,* the hyphae are then bundled into cordlike accumulations called rhizomorphs. Since these rhizomorphs grow and extend underground (in and around tree roots), a human observer sees nothing of this interwoven subterranean mat except for the occasional and spatially discontinuous mushrooms that poke through the forest floor.

Since we mistake an individual mushroom body for a discrete organism, we might look at the area of this *Armillaria* clone and, seeing nothing of the underground continuity, view the species as consisting of a few widely scattered, entirely separate items—a population of several insignificant individuals. But Smith and his colleagues, working in a forest near Crystal Falls on the Upper Peninsula of Michigan, found a region of some thirty acres underlain by the interconnected rhizomorphs of a single *Armillaria* clone. Extrapolating from best assessments of rhizomorph growth rates, they infer a minimal age of 1,500 years—probably a substantial underestimate since neighboring clones have inhibited further spread for some time, while the calculation assumes continuous expansion. They estimate the weight of rhizomorphs in the soil at about ten tons, but this figure excludes much of the clone's bulk growing in places harder to assess—for example, within tree roots and deep in the soil. Moreover, this figure excludes the mass of fine hyphae that extend from the rhizomorphs into surrounding soil and wood. Smith and his col-

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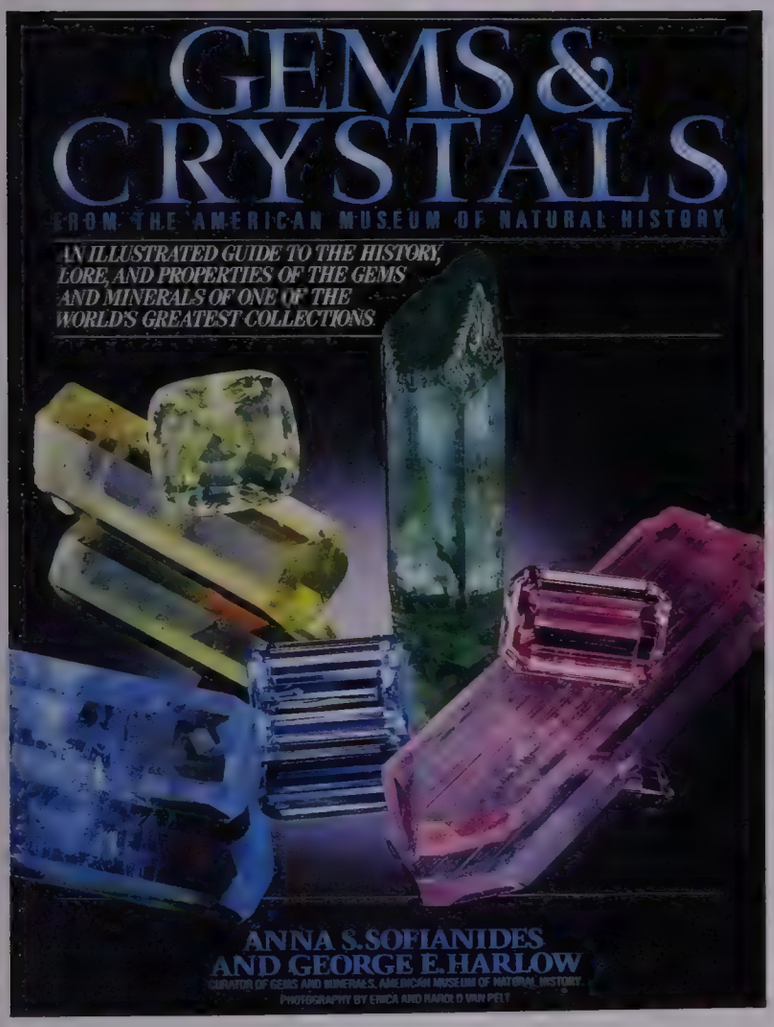
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leagues estimate that the weight of the entire clone may exceed their figure by ten times or more, yielding a total closer to 100 tons.

Thus, this champion *Armillaria* clone may weigh as much as a blue whale (although substantially less than a large sequoia) and probably lies in the ballpark of the oldest tree for age. Its claim to "firstest with the mostest" must rest upon the added criterion of lateral spread—in other words, of mushrooming. Thirty acres, however thinly distributed in spots, makes quite a creature. Even the Blob, of B-movie fame, will have to take a back seat.

As so often happens in the first flurry of commentary on scientific findings, the wrong aspects get emphasized and the truly interesting conceptual issues fall into the background. I can get as het up as the next guy about claims for maximal age, size, and weight. I know that Robert Wadlow nearly reached nine feet, that Robert Earl Hughes exceeded 1,000 pounds, and that Mr. Izumi of Japan lived past his 120th birthday. The Michigan clone of *Armillaria,* while falling short in weight, and perhaps in age, does enter my mental list as the biggest organic spread. But the deeper fascination of this tale lies elsewhere—in the striking way that this underground fungal mat forces us to wrestle with the vital biological (and philosophical) question of proper definitions for individuality.

First of all, the novelty of Smith, Bruhn, and Anderson's study lies not in the discovery of something so big but in the establishment of criteria to test the clone's status as an individual. Large and continuous underground mats of fungal rhizomorphs have long been recognized. Heretofore, however, we had no way of ascertaining whether or not they formed from a single source. Fungal spores are everywhere (as we all know from our experiences with bread mold). A single mushroom can produce up to a million fertile spores per hour over several days. With so many spores, representing so many different clones, falling all over the forest floor, why suspect that a large mat of rhizomorphs should represent growth from one initiating spore, and therefore count as a single individual by genealogy? Why not propose that such gigantic mats of rhizomorphs are actually congeries, or aggregations, made of products grown from several founding spores (representing many different parents), all twisted and matted together—in other words, a heap rather than a person?

Spores are certainly ubiquitous, but a constant rain does not guarantee a cooperative matting together to form massive aggregations, for organisms have immunological mechanisms for distinguishing self from nonself and rejecting amalgamation (abutting coral colonies do not generally fuse on growing reefs), while Darwinian theory views competition among different genetic units within a species as a major thrust of life's game. Thus, single versus multiple sources for large fungal mats has been viewed as an open and interesting question for some time.

Genetic tests are now available for resolving such an issue. Smith and colleagues first sampled several portions of the *Armillaria* mat both for genes that de-

termine compatibility in breeding (called mating-type alleles) and for several fragments of mitochondrial DNA. Both the mating-type and the mitochondrial genes are highly variable within the species *Armillaria bulbosa,* but all samples of the Michigan mat yielded the same array. This demonstrates close genetic relationship but does not prove individuality, for how can we know whether the mat is made from many highly inbred siblings or from a single founder? An additional genetic test then indicated a single founder. Repeated close inbreeding leads to a marked reduction of genetic variability among offspring—a presumed "deep reason" behind our various laws and taboos against incestuous marriage. Genes that are variable within an individual (called heterozygous because the maternal and paternal copies differ) will tend to become uniform in offspring if that individual mates with very close relatives. Smith and colleagues traced markers of several DNA sequences from heterozygous genes throughout the mat and found no reduction in their variability—a sign that the entire mat has grown from a single source and does not represent an incestuous amalgamation of numerous sibling subclones.

But this elegant demonstration that the Michigan mat formed from a single source only opens the more interesting and portentous issue of defining individuality—*the* central question, as we shall see, for applying Darwinian theory to nature. The Michigan *Armillaria* mat grew vegetatively from a single source, but does it qualify as an individual under our usual vernacular definitions? Clive Brasier addressed this question in a commentary that accompanied Smith, Bruhn, and Anderson's original article:

The suggestion of Smith *et al.* that [the Michigan mat] deserves recognition as one of the largest living organisms, rivaling the blue whale or the giant redwood, invites closer scrutiny. The blue whale and redwood exhibit relatively determinate growth within a defined boundary, whereas fungal mycelia do not.

In other words, a whale is a whale, with flippers and tail, but the Michigan mat just spreads. Moreover, we cannot be sure that the Michigan mat is truly continuous throughout. Pieces may break off and become physically separated from the main mass; but a whale's flipper, if broken off, is dead meat, not a miniwhale. Brasier concludes, with justice:

So although [the Michigan mat's] reputation as a champion genotype [discrete ge-

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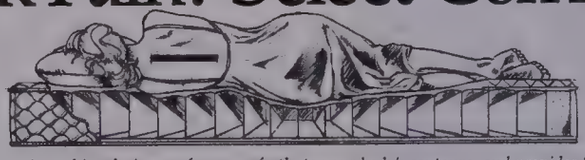

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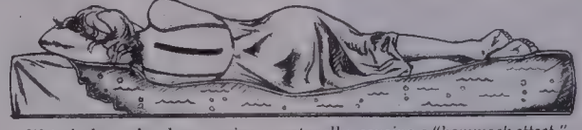

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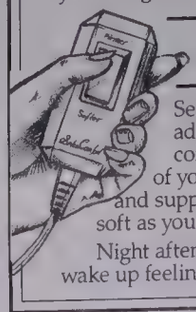

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netic system] may yet be secure, its status as a champion organism depends upon one's interpretation of the rules.

What, then, shall we accept as definitive of individuality, and why is this issue important to biological theory, not merely a verbal game? A single genetic origin followed by growth in physical continuity might represent a good first stab, but the Michigan mat raises a cardinal issue also illustrated by many other creatures, including grass blades and bamboo stalks (although the problem may only represent an unfortunate parochialism based upon our unfair extrapolation of what we know about the character of our own bodies to a false criterion for all life).

Our canonical individuals are bounded entities with definable form—a whale, a tree, a cockroach, a human being. By analogy, we wish to label a grass blade, a bamboo stalk, or a mushroom as an individual. But consider the proposed criterion of contiguity and unique genetic origin. A bamboo stalk looks like what we call an entire plant in other circumstances, but each stalk in a field may arise from a common system of underground runners, all united and all formed by vegetative growth from a single seed. Isn't the bamboo stalk then just an organ of this larger individual, as the mushrooms of *Armillaria* are only the visible fruiting bodies of an underground totality? (Bamboo stalks are giant grass blades, so the same argument applies to our lawns.)

Botanists, more often than zoologists, must deal with this problem of apparent organs that look like individuals (although a colony of coral animals raises exactly the same issue). Botanists have therefore devised a special terminology to treat these ambiguous cases of parts that are entire organisms in vernacular usage but organs of a larger totality by genetic definition. They speak of the morphologically well-defined part (the grass blade, bamboo stalk, or mushroom) as a *ramet* and the entire interconnected system (the underground runners and stalks, the mat of rhizomorphs with occasional mushroom buds) as a *genet*. In other words, the vernacular individual is a ramet; the genetic individual, a genet. This terminology does not solve the conceptual problem of defining individuality but merely devises names to acknowledge the classical case of inherent ambiguity.

The vernacular and genetic definitions can be driven even further apart by recognizing that even the chief character of connectedness can fail when we advocate the genetic criterion. In 1977, zoologist Dan Janzen wrote a provocative article on this subject in the *American Naturalist*, with the subheading: "What Is an Aphid?"

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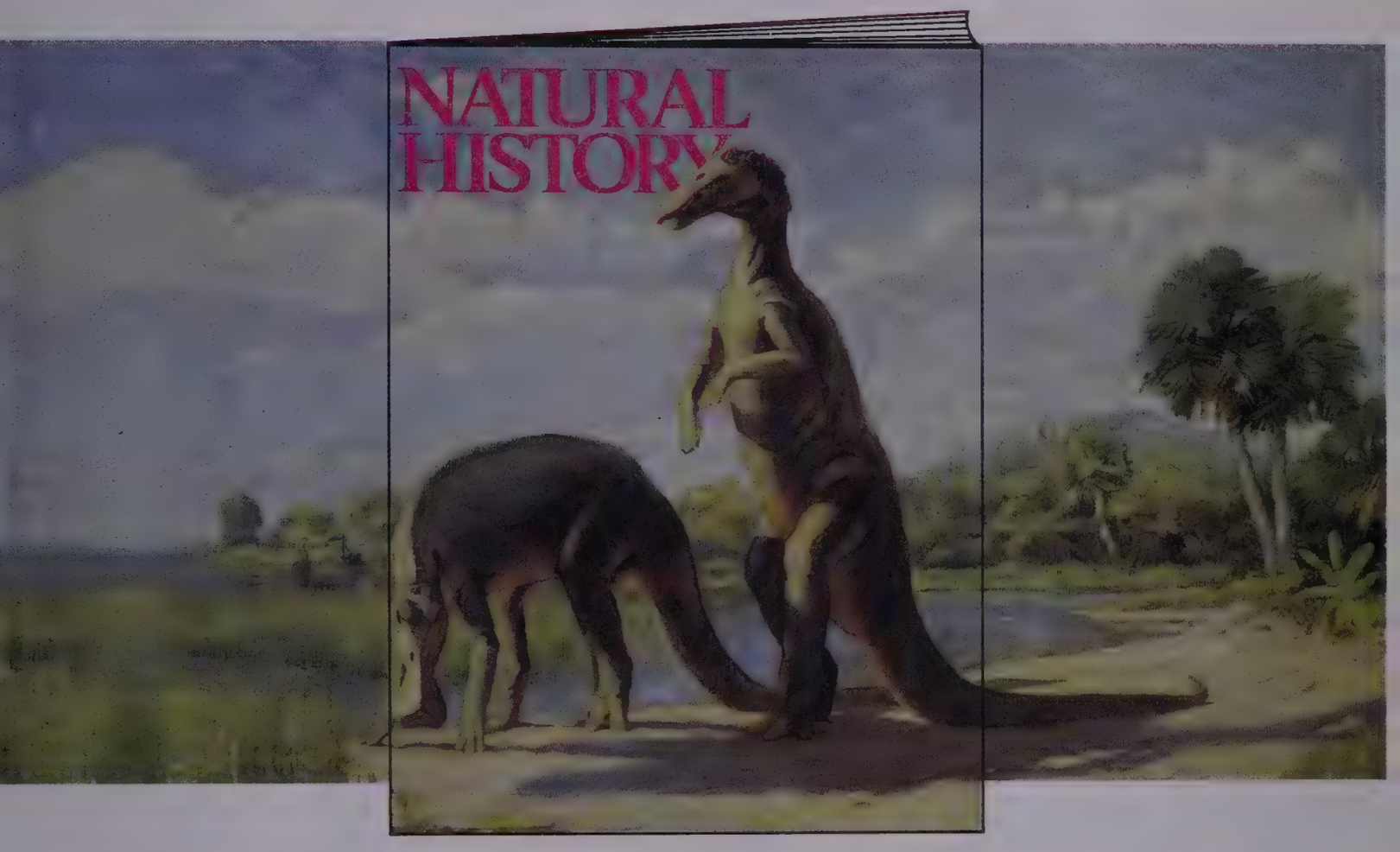

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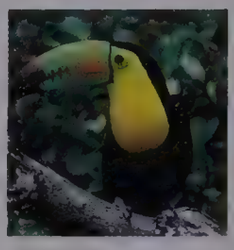

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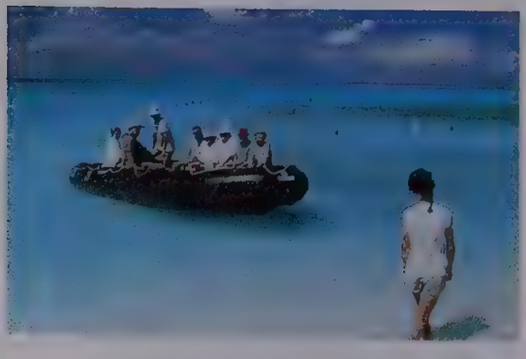

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Many aphid species breed sexually just once a year. Females born from this sexual union produce subsequent all-female generations by parthenogenesis—that is, without fertilization. The parthenogenetic offspring are all identical, both to their sisters and their mothers (except for rare new mutations). In other words, they form a clone of genetically identical bodies—and billions of aphids may ultimately arise from one stem-mother. (Eventually, the females begin to produce some male offspring and fertilization can then ensue—but this is a different story.)

Now what are all these aphid bodies in a single parthenogenetic clone? By any vernacular criterion, they are individuals. They look like any other unambiguously individual insect—like a cockroach, a ladybug, or a cricket. They have mouths and six legs, just like any ordinary insect. Yet they are part of one genetic system, all formed by an analogue of vegetative growth from a single starting point (the stem-mother). The entire clone of separated aphid bodies is just like the stalks of a bamboo field or the mushrooms of an *Armillaria* mat, but without the underground connections. The aphid bodies are disconnected ramets of a single genet. Why, Janzen argues, should we not label the aphid bodies as parts and the entire clone as a single EI, or "evolutionary individual"? This redefinition has some startling consequences, as Janzen notes (you may need to read this quotation twice to put yourself in its unconventional framework, but the implications are surely arresting):

> Each EI grows rapidly by parthenogenesis, with occasional pieces (aphids) being bitten out of it by parasites (in conventional discussions these would be called…predators). Only very rarely is an EI preyed upon (*i.e.*, all of it eaten), since part of its growth pattern is to spread itself very thinly over the surface of the plants in its habitat, so thinly that a potential predator is very unlikely to find all of it at once.

Before this sequence of increasing ambiguity becomes any more maddening, let me propose a different approach, and a potential solution. Terms are best defined within the context of explanatory theories. *Gravity* may have a variety of vernacular meanings, but its changing technical definition in the successive formulations of Newton and Einstein define its character as a scientific concept. Similarly, *individual* has a central role and meaning within Darwinian theory, our ruling paradigm for understanding nature. Shouldn't we accept this theoretical definition as our primary biological meaning? (The vernacular may stray, but science cannot and should not control all ordinary usage.)

Darwin's central postulate states that natural selection works upon *individuals* engaged in a struggle (metaphorical and without conscious intent to be sure) for reproductive success. Individuals that leave more surviving offspring obtain a Darwinian edge, and populations change thereby. Fine, but who is the "individual" engaged in such a struggle? Darwin gives us a clear answer: individuals are organisms—that is, conventional bodies (with some nuancing for ambiguous cases like mushrooms and aphids). Natural selection works on creatures—on individual lions fighting for a limited supply of zebras; on individual trees struggling with others for light.

This emphasis on ordinary vernacular organisms was central to Darwin's radical reformulation of nature, for he was consciously striving to overthrow the comforting and conventional idea of nature's intrinsic benevolence, with a creator fashioning good organic design and harmonious ecosystems directly. How delicious to contemplate that these "benevolent" results arise only as side consequences of a mechanism operating "below" divine superintendence, and having no "goal" but the selfish propagation of individuals—that is, organisms struggling for personal reproductive success and nothing else.

We continue to accept Darwin's abstract formulation today—individuals struggling for personal reproductive success—but a substantial rethinking has enlarged Darwin's concept of individuality. For Darwin, only organisms are individuals, or "units of selection." But what properties does an entity need to operate as a Darwinian individual—and are organisms the only such entities? We can specify five such properties: an individual must have a clear beginning (or birth) point, a clear ending (or death) point, and sufficient stability between to be recognized as an entity. These first three properties suffice to define an individual in the most abstract sense. But an entity requires two more properties to enter a Darwinian process of reproductive competition: it must bear children, and these children must be produced by a principle of inheritance that makes offspring resemble parents with the possibility of some differences.

Darwin was surely right that ordinary organisms (also *Armillaria* mats and aphid clones) possess these five properties: they are born and die at definable points; they are stable enough during their lifetimes;

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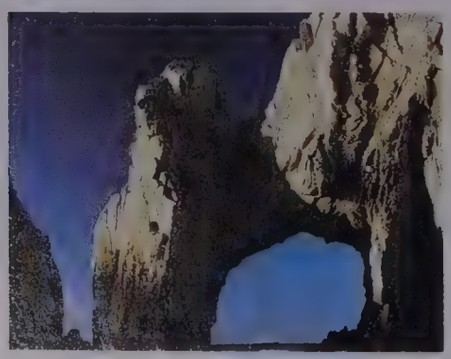

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and they have children that resemble them with the possibility of difference. Organisms can therefore be units of selection.

But what about entities either more or less inclusive than organisms? What about genes "below" organisms, and species "above"? We usually think of genes as *parts* and species as *collectivities,* but maybe this conventional view only represents the bias of restricted focus on our personal lives. Maybe genes and species are just as good Darwinian individuals as bodies. After all, species are born when a population becomes isolated and branches off from its parental stock. Species die unambiguously at their extinction. Most species are quite stable throughout their geological duration. Genes also possess the five key properties of birth, death, stability, reproduction, and inheritance with the possibility of difference.

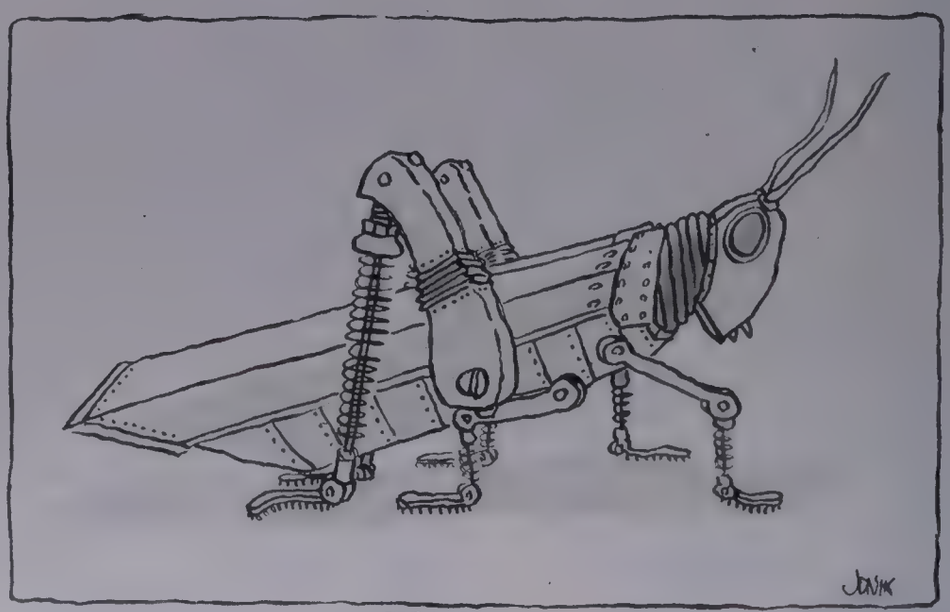
Thus, individuality extends beyond *Armillaria* mats and aphid clones to encompass different levels of biological organization—so different that we have usually called them parts or collectivities under the parochial assumption that only organisms can be individuals. Genes and species are also Darwinian individuals, and selection can operate upon them as well. Selection does not only sort organisms, as Darwin thought; it operates simultaneously at several levels of a genealogical hierarchy—on genes and cell lineages "below" organisms, and on populations and species "above" organisms. All these levels of the hierarchy produce legitimate Darwinian individuals—and this is the large, inclusive, and proper biological sense of the term *individual.*

Evolutionary theory does not operate as Darwin imagined when selection acts simultaneously upon several kinds and levels of individuals. Balances and feedback, rather than adaptive perfection, become the source of temporary stabilities. Fancy feathers are wonderful for an individual peacock but harmful (in geological time) for the individual species *Pavo cristatus.* Roger Clemens's salary is terrific for him and his family line but of dubious value for long-term persistence of the individual called Major League Baseball.

Nature is not an intrinsic harmony of clearly defined units. Nature is built by multiple levels, interacting fuzzily at their borders. We cannot even formulate an unambiguous definition of individual at the single level of organic bodies—as *Armillaria* mats and aphid clones demonstrate. Moreover, in Darwinian terms, legitimate individuals exist and operate at several levels of a genealogical hierarchy—genes and species, as well as organisms. But what a fascination when this maelstrom of differing individuals forms its meshwork of interaction to produce life's history by Darwinian evolution. Does nature herself then sing Walt Whitman's *Song of Myself?*

> Do I contradict myself?
> Very well then I contradict myself,
> (I am large, I contain multitudes.)

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.



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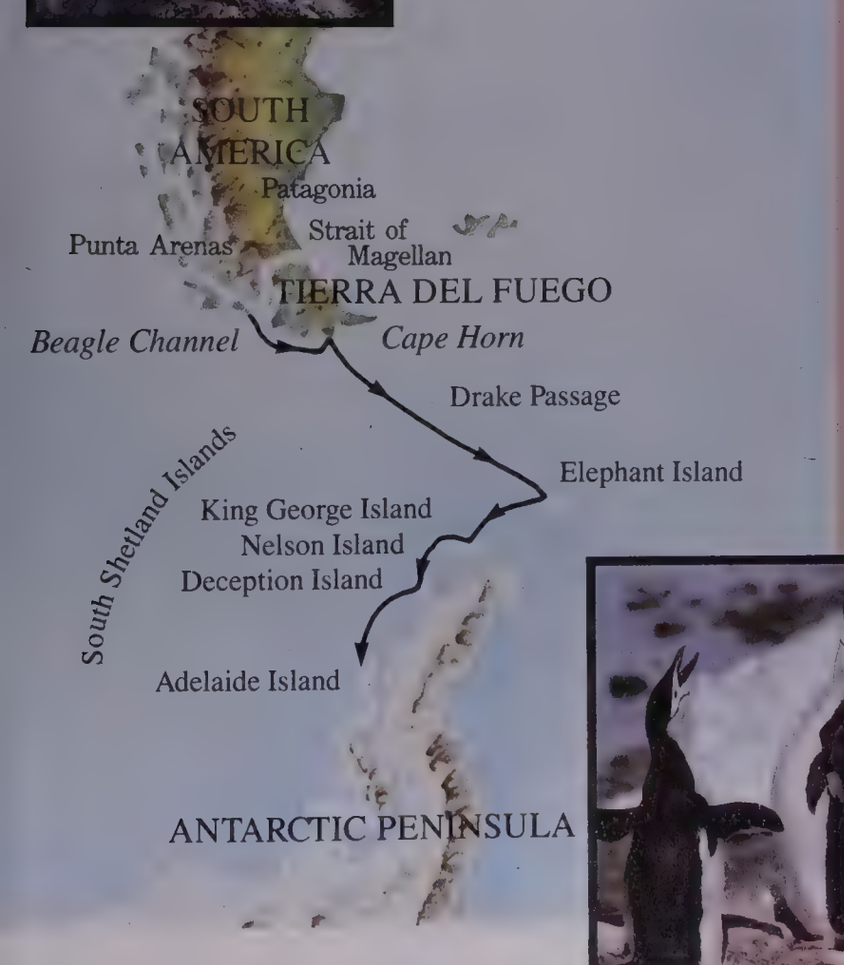

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The Gardeners of Eden

A bouquet of exotic flowers was one trophy of European expansion

by Samuel M. Wilson

Gardens and gardening flourished during the Italian Renaissance, reflecting both the rebirth of interest in classical philosophy and aesthetics and the emergence of the natural sciences. The remarkable *Natural History* written by Pliny the Elder (A.D. 23–79) was resurrected as holy writ by Renaissance gardeners. Pliny's principles are still adhered to in modern gardens, especially his emphasis on integrating the rooms of the villa with the "rooms" of the garden and the importance of maintaining harmony between the villa garden and the surrounding landscape.

The villa at Careggi was just one of the country estates that the Medici family of Florence owned in the late 1400s, but its Renaissance garden was Lorenzo de' Medici's favorite. He spared no expense in researching and obtaining the most exotic plants for it: a fifteenth-century poem by Alexander Bracci lists more than 100 species that Lorenzo planted. Leonardo da Vinci, who lived from 1452 to 1519, spent considerable time at Careggi, creating sculpture and perhaps even designing parts of his patron's cherished garden. As botanist William Emboden has shown, Leonardo was as passionate a student of botany as he was of nearly everything else in his world. His voluminous notebooks contain thousands of detailed sketches of plants, with notes on their characteristics (set down in his mirror-image handwriting), as well as sketches of gardens.

More than four centuries later, in another country, I too keep a garden. Mine is certainly not impressive by any measure, even compared with those on our street. But my international hodgepodge of plants would have thrilled Lorenzo de' Medici, Leonardo da Vinci, and Pliny the Elder. Leonardo never saw the explosion of New World plants into the gardens of Europe and the rest of the world. He mentions only one or two Native American plants in his notebooks—corn (maize) and possibly a New World bean. He died just as Cortés's expedition was making its way toward the Aztec capital and some of the world's most remarkable gardens. So Leonardo never tasted chocolate, one of the things Cortés brought to Europe.

Describing the extraordinary things Cortés and his army saw in Montezuma's palaces, Bernal Días del Castillo wrote, in *The Discovery and Conquest of Mexico:*

> We must not forget the gardens of flowers and sweet-scented trees, and the many kinds that there were of them, and the arrangement of them and the walks, and the ponds and tanks of fresh water where the water entered at one end and flowed out of the other; and the baths which he had there, and the variety of small birds that nested in the branches, and the medicinal and useful herbs that were in the gardens. It was a wonder to see, and to take care of it there were many gardeners.

The sixteenth-century chronicler Fernando de Alva Ixtilxochitl was born to a noble Aztec family but educated in Spanish mission schools. In his *Historia Chichimeca* he described the precinct of the Aztec aristocracy as a huge walled park, containing palaces, temples, and the buildings of the state bureaucracy. The rest of the precinct was given over to gardens

> with many fountains, ponds and canals, many fish and birds, and the whole planted with more than two thousand pines...and there were several mazes, according to where the king bathed; and once a man was in he could not find the way out...and farther on, beside the temples, there was the bird-house, where the king kept all the kinds and varieties of birds, animals, reptiles and serpents that they brought him from every part of New Spain; and those which were not to be had were represented in gold and precious stones—which was also the case with the fish, both those of the sea and those

The Renaissance garden of the Medici family's villa at Careggi contained many spectacular plants, most from the Mediterranean and Near East.
Ghigo e Lorenzo Roli, Italy; Grazia Neri

that lived in rivers and lakes. So no bird, fish or animal of the whole country was wanting here: they were there either alive or figured in gold and gems.

In the 1570s, Francisco Hernández and a group of Aztec artists and draftsmen made a large compendium of Aztec plants. Unfortunately, the original drawings, containing additional notations and details in the Aztec language, Nahuatl, were destroyed in 1671 with a large part of the famous library at El Escorial, a Spanish palace and monastery. But copies of them appear in *Historia Naturae Maxime Peregrinae* (1635), by the Jesuit Juan Eusebio Nieremberg.

Another source describing the Aztec flora is the 1552 *Badianus Manuscript*. This extraordinary catalog of medicinal plants, with still-vivid, natural-dye illustrations, was made by two Aztec scholars educated at the Colegio de Santa Cruz de Tlateloco. Martinus de la Cruz composed the text, and Juannes Badianus translated it into Latin. The book sat in the Vatican library for nearly four centuries before its facsimile was published in 1940.

Many of the New World's most spectacular contributions to modern gardens were slow to appear in Europe. The conquerors paid more attention to crops that could be profitably sold. Two of the most addictive, and thus most profitable, were cacao (the source of chocolate) and tobacco. Tomatoes were slower to catch on in Europe, only becoming widely grown in the late nineteenth century, surprising as this may seem to those of us somewhat addicted to tomatoes.

Potatoes, squashes, pumpkins, arrowroot, manioc, and other food plants were not addicting but became popular and important in many parts of the world. Some Native American crops, like the peanut, have come into their own only in the last century or so. And some, like the wonderful Jerusalem artichoke, a member of the sunflower family, have not yet become popular but should (its intriguing name is a corruption of the Italian *girasole*, meaning "turn to the sun").

The chili pepper (*Capsicum annuum* and others) well illustrates the massive diffusion of plants that has taken place since 1492. In his journal of the first voyage, Columbus noted:

> There is also much chili, which is their pepper, of a kind more valuable than [black] pepper, and none of the people eat without it, for they find it very healthful. Fifty caravels can be loaded with it each year in Hispaniola.

This remarkable plant—domesticated, bred into dozens of varieties, and cultivated in the New World for thousands of years—made its way around the globe in just a few decades. The spicy cuisines of South Asia, Thailand, Vietnam, and Sichuan in China are unimaginable without chili.

Scholars have often noted the dramatic effect of the exchange of New and Old World food plants—including corn, potatoes, and tomatoes going one way and wheat, rice, and bananas going the other. In sheer numbers of species, however, the relocation of ornamental plants has been vastly greater than the movements of economically important species. Ironically, many domesticated and well-bred New World ornamental plants, left to fend for themselves when their gardeners died or left their gardens, were rediscovered by Europeans as "wild" flowers.

The twelve species of dahlias grown by the Aztecs were warmly received in Europe, but they did not reach England until 1790. The zinnias and marigolds were probably grown earlier in Spain and other Mediterranean countries but were first recorded in England in 1753. The glorious lilies of the Andean Incan gardeners, such as the hardy amaryllis, the Peruvian lily, and rain lilies, are widely cultivated today. Both Incan and Aztec gardeners grew many varieties of bromeliads (relatives of the pineapple, another New World domesticate), whose vast family spreads over all the tropical Americas (*see* "Epiphytes of El Yunque, Puerto Rico," *Natural History,* October 1991).

Others among the countless New World flowers in global cultivation are phlox, morning glory, fuchsias, Michaelmas daisies, and yuccas. Anyone who gardens is probably growing New World domesticates, including those who dedicate all their efforts to trying to grow the elusive 1,000-pound pumpkin. Thousands of wildflowers are also finding increasing popularity among gardeners. Just a few of the sophisticated native plants I have growing in my garden are the primrose, Mexican mint marigold, butterfly weed, black-eyed Susan, and hairy zexmenia.

Such wild plants are the raw material for gardeners. With food crops, cultivators can select for edible wild plants that yield more food per plant, are better suited to particular conditions, more hardy, and so forth. Gardeners select blooms and foliage for size, form, texture, and color. Five hundred years ago, the New World, Asia, and Africa were full of raw material for plant domestication, while Europe had relatively little. In *The Principles of Gardening,* Hugh Johnson argues that the flora of Europe suffered much greater damage during the last glaciation than did that of Asia and the Americas. In North America and China, plant communities survived by migrating southward as the glaciers crept forward, and they recolonized as the glaciers retreated. European plants were cut off by the Mediterranean Sea, and only the most hardy survived.

A passionate student of botany, Leonardo da Vinci filled his notebooks (written in mirror-image script) with countless sketches of plants. Although many of his drawings were made in the sixteenth century, only one or two were of native American plants.
Giraudon/Art Resource, New York

Europe's colonial expansion changed that, and European gardens began to fill with the exotic flowers of Africa, Asia, and, eventually, the Americas. The rose represents a delightful combination of the musk rose of the Mediterranean and Near East and the Chinese rose, neither of which in its wild form is as glorious as the hybrid offspring. The Renaissance painter Botticelli sprinkled some of the early hybrid roses around in the background of *The Birth of Venus*. We have seen only a few centuries of the combination and recombination of the lesser-known species in the world's flora, and other startling hybrids have yet to appear.

Europe's expansion was driven by a growing population and an even faster growing aristocracy, which generated a demand for gold, spices, and other rare and exotic goods. Columbus sailed west to find a quicker route to these luxuries, a good shipload of which—safely delivered—could allow a captain to retire for life. While they might seem secondary in importance to economic crops, exotic ornamental plants, destined to grace the celebrated gardens of the Renaissance aristocracy, were valued for their aesthetic properties. Just as I can imagine an Aztec king conquering whole provinces to obtain the twelfth dahlia, I am confident Lorenzo de' Medici would have been willing to pay more than the total cost of Columbus's first voyage to get a few more specimens for his garden at Careggi.

Samuel M. Wilson teaches anthropology at the University of Texas at Austin.

Bait and Switch

What's the difference between an australopithecine and an automotive parts store?

by Roger L. Welsch

People are always interested in origins. What were the beginnings of the universe? What causes mountains? Who invented the chia pet? Who put the "bop" in the bop-she-bop-she-bop? Who put the "ram" in the ram-a-lam-a-ding-dong? Questions like these could remain the subjects of campfire conversations and the grist for academic mills, but increasingly, Americans are staking their positions in important social conflicts and legal wars on the basis of cosmic posers. So, I'm going to clear things up right here and now by surveying everything we know about the origins of life and humans. Then, if I have any room left at the end of this column, I'll throw in my recipe for catfish bait.

I have always supported the idea of teaching creationism in schools, right alongside geology, paleontology, and other old-stuffologies. The only complication that troubles me is the choice of which creation stories we are going to include. The dilemma is being resolved in part by scientific and biblical approaches squishing together. I read somewhere that clay may be the fossil remains of the earliest forms of life, which fits in quite nicely with the biblical notions of human origins. "A-dam" means "from the earth." (And then there's "dust thou art, and unto dust shalt thou return," which has always struck me as a remarkably square deal, considering.) So science says, "dirt," and the Bible says, "dirt." Next problem.

Dilemmas are best resolved and questions best answered, an old-timer once told me, by solutions that convince each side that it has won or, at a minimum, that the other side has lost. Thus, we should be grateful for the ambiguity made evident in jokes like the one about the little child who comes home from Sunday school, having discussed the "dust-to-dust" thesis, and tells her mother that someone is under her bed, but she can't tell whether he is coming or going.

My own early confusion about this issue came from a conversation I overheard when I was an inquisitive stripling. A bunch of dopes who probably couldn't have told the difference between an australopithecine and an automotive parts store were arguing evolution when one genius brought things to a halt by demanding to know why, if evolution was indeed fact, scientists had never found the missing link. "Be...be...because," stuttered the smartest guy in the huddle, "*we're* probably the missing link!"

Some scientists seem embarrassed when their conclusions suit creationists, and vice versa, but plenty of doubt remains to provide ample antagonisms for both sides for a long time to come. To me the most appealing version of creationism socked me in the face one day when I was visiting a Native American shirtmaker in a pueblo in New Mexico. As I entered his workshop, I noticed a large, peculiar stone in the pueblo's plaza, about fifty feet from his doorway; the stone was striking not only because it was large and the only stone in the plaza but also because it had feathers, ribbons, and little mounds of cornmeal on it and the only grass I could see in the village was growing in a ring a couple of feet around the stone.

"What's with the rock?" I asked.

"It's the earth's navel," the Indian craftsman told me. "That's where mankind came up onto the earth from the underworld. Then the first humans rolled that rock into the hole to keep monsters from following them up here."

Now, imagine the following three conversations and consider their implications for religion, science, and education:

CONVERSATION NO. 1:

KID: Hey, Reverend, where did the first men and women come from?

PREACHER: The Bible tells us that God created them, man from dust and woman from man's rib, and they were put in the Garden of Eden, but they tasted of the fruit of the tree of knowledge against his will, and so he made them ashamed and kicked them out of the garden.

KID: If they ate of the tree of knowledge, how come there are so many dumb people around today? Why would God create knowledge if he didn't want people to have it? And if knowledge is so bad, why do I have to go to school? And where is the Garden of Eden?

PREACHER: Uh, God destroyed it. It was somewhere around Iraq.

KID: Uh-huh.

CONVERSATION NO. 2:

KID: Hey, Mr. Science, where did men and women come from?

MR. SCIENCE: It's pretty complicated, but through the long and elaborate

"I'm it. There was a crackdown by the Humane Society."

processes of evolution, humans evolved from the primordial oozes, then became squishy things, then creepy things, and then scary things, and now here we are.

KID: How come deer inherit speed, dogs inherit a good nose, cats inherit balance, birds inherit the ability to fly, and we humans don't inherit hardly anything worth bragging about?

MR. SCIENCE: Natural selection and environment and heredity and some things we still don't understand. Besides, I'm awful busy.

KID: Uh-huh.

CONVERSATION NO. 3:

KID: Hey, Mr. Indian, where did men and women come from?

INDIAN: Over there, from under that rock.

KID: Oh.

And now, as if it weren't enough of a job for philosophers like me to come up with an explanation for the origins of humankind, struggles in courts and legislatures have also thrust on us the issue of when life begins in the individual. Well, right off, I think we can forget the Stella Dallas thesis of a couple of generations ago that life begins at forty. To be honest, I already have real doubts about sixty.

I asked around town and got a good random sample of what today's Americans think about the problem of when life begins. Stefanie Steffenhagen, sixteen, says life begins when you get a driver's license; my folks say that life begins when the children leave home. On the other hand, I could point out a couple dozen kids around town who are prima facie evidence that human life doesn't begin at birth, and maybe not even by junior high school.

Slick, up at the tavern, says that he was party to a discussion the other day that just may speak to the problem: One old-timer said that his memory was so good, he could remember the priest putting water on his head at his baptism. The second topped that by saying that he could remember the look on the doctor's face when he was born. The third walked away with the morning's prize, however, when he claimed that he could remember going to a dance with his father and coming home with his mother.

I'm not even sure it makes any difference how much intellectual energy industrial-grade thinkers like me devote to such problems as "How did humankind begin?" and "When does life begin?" because just as sure as we start picking away at one end of the issue, we lose ground at the other end. For example, up until recently, even though there was considerable argument about when life begins, there wasn't much doubt about death.

Well, hah! Science, philosophy, and folklore are now conspiring to blur the clarity of even that final rite of passage we always thought we could count on. The Nebraska legislature is currently considering a Living Will Bill that will make it possible for you to tell people when you think you ought to die, although there is still considerable question in the State House over whether your death is really any of your business. And yesterday's newspaper had an Associated Press release that human conception can occur with dead sperm! And prisoners on death row are demanding the right to conceive new life even though they have taken it upon themselves to terminate lives-in-progress. And what about Elvis Presley? What's that all about?

Slick, Dannebrog's sage and bartender, has taught me most of what I know about life, and as usual he managed to put a pretty good edge on this issue, consolidating all my confusions about origins, life, and death into one grand confusion. I threw my philosophical cards on the table and said, "Slick, ol' buddy, what do you think?" And Slick said, "You live and you learn. And then you die and forget it all." Good advice if I ever heard it, and there's no room left for my catfish bait recipe.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

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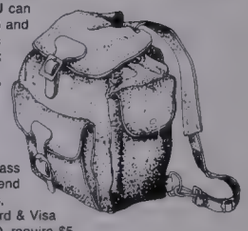

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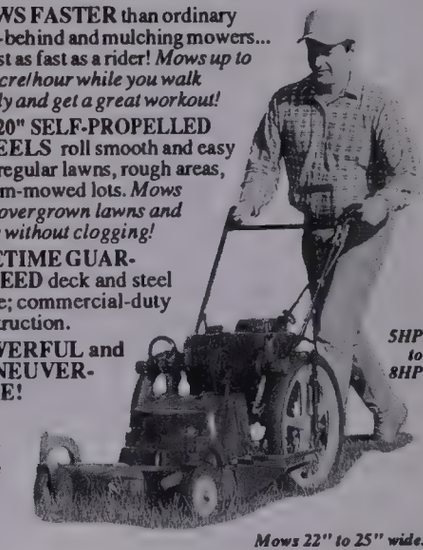

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Hundreds of Bewick's swans spend the winter at the Wildfowl and Wetlands Trust reserve on the flooded pastures of the Ouse Washes, Cambridgeshire, England.
Eckart Pott

Swans *Semper Fidelis*

Bewick's swans pair for life and are faithful year round

by Dafila Scott

In the early 1950s, Bewick's swans, the smallest of the northern swans, first began visiting the estuary of the Severn River in the west of England. Occasionally, they flew into the newly established enclosures of the Wildfowl Trust in Slimbridge. This organization, now known as the Wildfowl and Wetlands Trust, was set up in 1948 by my father, Sir Peter Scott, and is devoted to the conservation of waterfowl. In the collection of captive birds at that time were some whistling swans. Now known as tundra swans, these birds are close North American kin of Bewick's swans; the two are races of the same species. The captive tundra swans attracted their wild confreres, and when the captive swans were moved to the pond in front of our house in February of 1964, the wild swans followed and also landed on the pond. Within a week, all twenty-four swans in the vicinity were flying in daily from the estuary half a mile away.

Within a few days, my father realized that individuals could be recognized by differences in the black-and-yellow patterns on their bills. These were like fingerprints, but much more obvious, and enabled us to give each bird a name (which we thought easier to remember than numbers). In mid-March the swans departed on migration, undertaking a 2,400-mile flight to their breeding grounds in the Russian Arctic. The following November, familiar individuals returned to Slimbridge bringing their young, or cygnets, of the year and also some of their "friends." (Some of the swans that breed in Russia winter in eastern Asia; others in western Europe, mainly in the Netherlands and the United Kingdom.) Sixty-eight swans were recorded at Slimbridge in the winter of 1964–65, and the following year the total was 147.

I became hooked on Bewick's swans early in 1966, when I was thirteen. Sent home from school because of an illness and forbidden to go out-of-doors, I spent much time staring out the window at the beautiful white birds floating on the pond. To my surprise, I found I could easily identify individual swans, and I soon learned to recognize the whole flock. More and more swans arrived at Slimbridge each year; one day in early 1971, we counted more than 400. Since then, annual numbers have leveled off at about 500. Over the years, our interest grew into a long-term study that involved not only me and my parents but also colleagues, such as Mary Evans and Eileen Rees, who have spent more than ten years studying the swans. By 1988, we had named more than 5,000 swans. Each bird has its own dossier with arrival and departure dates, identity of mate, portrait drawing, and photo where possible. We also record the number of cygnets associated with a pair each year as a measure of breeding success. By finding out the lifetime breeding success of individuals, we can discover which birds will leave more genes in the next generation.

Because remembering an ever increasing number of different faces proved difficult, and also because we wanted to document the swans' migratory movements, we have caught and marked more than

Ryukichi Kameda; Nature Production

An adult Bewick's swan, attended by three juveniles, threatens an opponent (out of picture), below. Adult males often engage in dominance battles, cheered on—through calling and body language—by their mates and offspring. While many of the Bewick's swans that nest in the Russian Arctic spend the winter in England and the Netherlands, others head east. In Japan, wintering Bewick's swans, right, share wetlands with ducks.

Philippa Scott

2,500 swans, using large plastic rings that can be read up to 200 yards away in good light. We have also devised a computer code for the bill patterns of unringed birds.

In 1972, we also began studying Bewick's swans at the Wildfowl Trust's reserve on the Ouse Washes at Welney in Cambridgeshire. There, in the heart of the flat fenlands, the birds roost on the flooded pasture of the Washes between two artificial rivers dug in the sixteenth century. Recently, the swans have "discovered" winter wheat; by day they graze on the wheat or eat waste potatoes in nearby fields, returning to roost in the evening.

Because individuals are so easy to distinguish and return each year to the same wintering place, we have been able to follow the lives of many swans. After decades of observation we are now able to answer some basic questions, such as how long Bewick's swans live, whether pairs stay together for life, how many cygnets they raise in a lifetime, and why some raise more healthy young than others.

Our studies at Slimbridge and Welney have shown that most individuals that survive their first winter go on to live to about twelve years of age, although some live much longer. Our oldest, Prongy, failed to return only after her twenty-sixth winter. Individuals do indeed pair for life. We have recorded no case of divorce among pairs that have raised young and only twenty cases among a thousand pairs that never bred successfully.

Bewick's swan partners not only remain faithful to each other over many years but also keep close company within winter flocks. At first I wondered why this intimacy was necessary. Then I discovered at Welney that there was considerable competition within flocks during feeding and that winners of disputes gained access to good feeding sites—a dense patch of waste potatoes, for example—at the expense of their opponents. Pairs almost always displaced single swans; the reverse was infrequent. By following members of pairs, I confirmed that when they were together they won a higher percentage of contests than when they were separated. This held true even for high-ranking pairs in the swans' social hierarchy. Both partners benefited from being together because they were able to feed without being bullied off the choicest sites; but since females didn't fare as well as males when separated from their partners, they gained slightly more from the association. I believe that is because the ability to win fights is related to body size, and males, at about thirteen pounds, are 13 percent larger than females.

While this may explain the importance of staying together over the short term, it does not explain why partners remain faithful for many years, even when they fail to raise young. By following the histories of known pairs, we have discovered that the longer they stay together, the more offspring they raise per year. During the first eight years after pairing, success in raising young gradually increased, the greatest improvement being between the swans' first and fifth years as a pair. This improvement was independent of the chronological age of the birds. Most birds had only one mate during their lives, but swans that lived to age thirteen had a better than 50 percent chance of having more than one mate. (As a swan aged, the chances of its mate dying increased.)

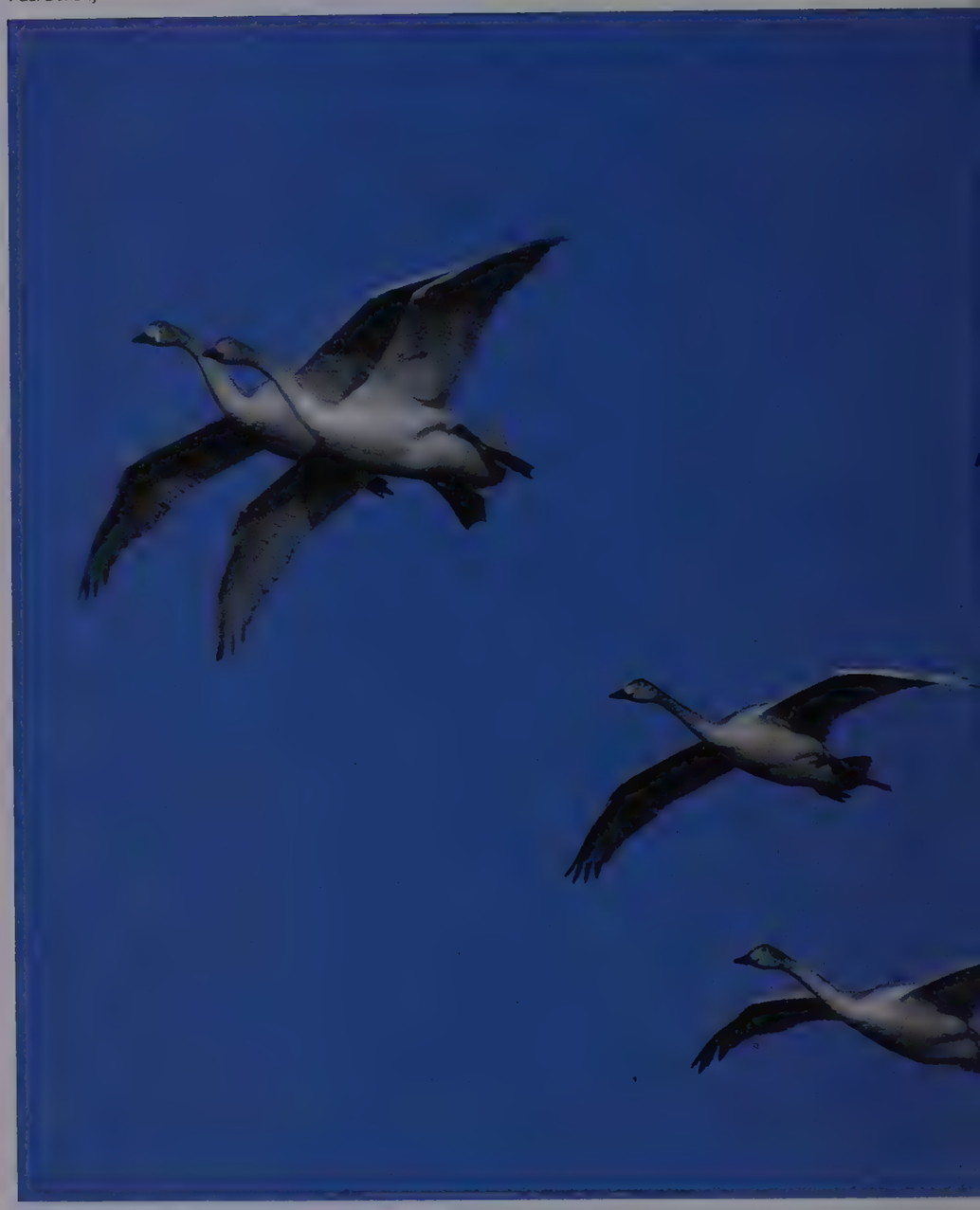
Even when they remated, these widows and widowers showed lower breeding rates, partly because 40 percent of them took more than one year to find another mate (and a few took up to six years). In addition, the new pairs seldom reared

cygnets in their first or second year together. Even birds at peak breeding age (six to ten years) usually took two years before breeding with a new mate, and older birds took slightly longer. Partners may simply need some time to learn to get on with each other. Overall, the more mates a swan had during its life, the fewer total young it raised. So fidelity is important, and loss of a spouse is not only sad but also costly in a reproductive sense.

In October and November, as the first wild swans descend from the autumn sky, we try to guess which pairs will bring cygnets. These are usually dominant pairs, and after they alight, much bugling and wing waving ensues as they dispute with other pairs to establish their positions in the winter hierarchy. Rankings established at this time usually remain stable for the rest of the winter and are the same wherever contestants happen to meet—either on the roosting site or out in the fields or flooded pastures where they feed. Dominance displays are spectacular and have often led people to believe that the swans are singing or dancing. Arguments between pairs begin with the birds stretching their necks low over the water and calling. Then they pump their heads up and down and may half open their wings. If this does not deter the opposition, the contest escalates. Both partners of each pair may spread their wings fully and flap them up and down, performing a bugling duet at the same time. If the opponents are equally matched, the males will resort to physical combat. They grab each other at the base of the neck and beat each other with their wings until one opponent gives up and flaps away. Sometimes the females join in by fighting with each other, but fights between males finally determine which pair dominates. More often, females are content to cheer on their mates with calling and head-pumping movements. Cygnets join in the cheering but never fight.

My first insight into the importance of the family unit in winter came as I watched the swans feeding on flooded meadows. I realized that the cygnets profited by their parents' ability to drive away competitors. Although the cygnets were three-quarters the size of adults by this time, when they moved away from the family group, they were often threatened by other swans and were sometimes unable to counter the threat and drive off the aggressor. But when they were close to their parents, cygnets were seldom threatened, and if they were, they could usually resist the opponent either alone or by calling their parents to them with high-pitched squeaks. When cygnets were separated from their parents by more than a few yards, they also spent less time feeding than when they were close to them. Orphaned cygnets spent little time feeding; when they found a good source of food, they were frequently displaced from it. In general, parents dominated pairs without young, providing effective protection for their cygnets. Offspring of dominant pairs did best. But even offspring of subordinates benefited by keeping close to them.

Paul Doherty



We do not yet know how much it matters to cygnets whether their parents are dominant or subordinate, but current evidence suggests that parental status may have a great impact on their lives. The offspring of dominant parents are themselves dominant as adults. We are waiting to see whether they also produce more offspring.

We have little information on the behavior of individuals on their arctic breeding grounds. Last year for the first time, my colleague Eileen Rees and I were able to visit the Russkiy Zavorot Peninsula, which lies north of the Pechora River Delta in the Nenetskiy National District of Russia, where Bewick's swans fitted with leg rings have been sighted in the past. Until recently, this area was a restricted zone even for Russian citizens. After many years of waiting and hoping, we were especially excited when permission for our trip came through.

Our aim was mainly to assess the population density, that is, the number of Bewick's swans on every square mile on the peninsula, now a protected area, and to compare this with previous estimates. But we were also keen to identify known individuals from Slimbridge and Welney. Imagine, then, our excitement when, on our second day on the tundra, after trudging across soggy ground against an eye-watering wind, Eileen thought she saw a white ring on the leg of one of a pair of swans nearby. I looked through my scope and confirmed that the bird was indeed ringed. At this point the problems began. The swans are very wild on the tundra, seldom allowing a viewer to approach within 300 yards. So in the end, we were unable to identify this swan either by bill pattern or by reading the leg ring. We saw two more of our ringed swans in the course of our stay and managed to identify one of these, which turned out to be a swan named Ieuan (the Welsh version of Ian), first identified in December 1990 in England. This male hid behind his mossy nest mound so as not to draw attention to its precious contents of four eggs—a typical clutch size. He finally got up and took off when I came within fifty yards. We have seen him again this winter in his traditional wintering site in Lancashire, but sadly he had no young in tow.

Studies of tundra swans in Alaska have shown that individuals tend to return to the same site to breed in successive years, as do Bewick's swans. The results of our surveys showed that the population density of Bewick's swans on the Russkiy Zavorot Peninsula has increased since 1980, a good sign. However, the area is surrounded by oil fields of potential economic importance, and we hope that the Russians will continue to safeguard this haven for swans and other waterfowl.

One thing about the tundra is certain: the timing of the spring thaw varies each year, and this crucially affects many species of birds, including Bewick's swans. If the snow melts early, the swans can build their nests and start laying early, and the water plants, which the family will need as food, can reach greater productivity earlier. Late thaws delay egg laying, and late-hatching cygnets have less chance of fledging before autumn arrives. In good years, when the thaw is early,

A family of Bewick's swans glide over the Welney wetlands, below, left. Bewick's are relatively small swans, with an average wingspan of seven feet. Even pairs of long standing engage in courtship displays on the wintering grounds, below. Copulation usually takes place during the spring migration or when the birds arrive on the tundra.
Philippa Scott; NHPA

many pairs return with young, and cygnets may make up as much as 25 percent of the winter population. In other years, the number of cygnets drops to only 7 percent. We look forward to collaborating further with our Russian colleagues to discover in more detail what factors affect the breeding success of swans on the tundra and whether swans born in good years or in poor years fare differently as time goes on.

Recently, I have been investigating individual differences in lifetime breeding success. Some pairs manage to raise healthy young in poor years, while others fail to do so even in good years. Although successful pairs usually return to England with two cygnets, they almost never return with more than five in one year, and the total varies greatly over the lifetime of different swans. Of those swans that survive to breeding age and pair, some fail to raise any young during their lifetime, while one pair we ringed, Pangle and Poppylot, produced forty-two young in eleven years. What made this pair and a few others that topped the thirty mark so successful? They all had one thing in common: the male was large.

Over the long term, dominant pairs and larger males and females raise more young. When all other factors were constant, the only significant predictor of such success was the size of the male, as measured by his skull length. I had previously thought that one male characteristic (perhaps size) and one female trait (perhaps body condition) might be equally vital to long-term success in raising young, and I was surprised to find that male characteristics appeared consistently more important.

We do not know if as yet unmeasured female characteristics will prove as important as male size in determining breeding success. If male characteristics are more important, then the females that re-pair should show a greater change in breeding rate than do males that re-pair. Although rate of breeding may increase or decrease dramatically in either sex after re-pairing, my data show a significantly greater change in breeding rate among females that take new mates on the death of their spouses. So, on present evidence, male characteristics appear to have the greatest bearing on the number of cygnets raised over the long term.

Why should male size be critical? I believe this relates to fighting ability. Only the outcome of fights between males determines relationships between pairs. In winter they fight for access to food, roosting sites, and dominance within the flock, while in summer they fight for breeding territories. My observations of territorial behavior among breeding Bewick's swans in Russia agreed with those that I had made on tundra swans in western Alaska in 1976. At both sites, the swans' breeding territories are large, up to half a square mile in area. Pairs unable to obtain territories must forgo breeding for that year and be content to join a nonbreeding flock. Competition is fierce; observers have reported tundra swans fighting to the death

An immature Bewick's swan will acquire adult white plumage and a characteristic black-and-yellow bill at about one year of age.
Ernest Duscher; Bruce Coleman, Inc.

to secure territories. My own observations in Alaska showed that territorial defense throughout the breeding season was undertaken mainly by the male, while the female was responsible for two-thirds of incubation duties and spent more time with newly hatched young. Our preliminary observations in Russia this summer confirmed this division of labor for Bewick's swans as well. The likelihood of large males winning more fights and maintaining a good breeding territory may explain why male size is so important to pairs.

Except for their disparity in size—known as size dimorphism—male and female Bewick's swans are outwardly identical. In many other monogamous birds, such as storks, the sexes are alike in both size and appearance. Unlike swans, however, storks share rather than split various nesting duties. Perhaps male swans must be large for territory acquisition and defense, while females must be smaller to conserve energy during the rigors of egg laying and incubation.

With this in mind, I examined the literature on the whole range of waterfowl species, most of which are monogamous either over the long term or serially. Three significant factors were associated with size dimorphism: territoriality, nesting, and pairing habits. As I predicted, territorial species were more dimorphic than nonterritorial ones. Hole-nesting species and those that took new mates annually showed greater size dimorphism than did open nesters and those with long-term pair bonds. These results suggest that the importance of territorial defense may indeed explain the size of male Bewick's swans.

To do justice to birds that live long and breed into old age, such as swans, we need long-term studies. To assure that Bewick's swans thrive in the future, we must turn our assumptions into facts and learn their natural history on both their wintering and breeding grounds, from England to the Arctic and back. Legendary for their fidelity, the swans have inspired in our researchers some of the same loyalty that the birds themselves display. □

Using his own saliva and heat from the ritual fire, the shaman's son Leonid tunes a reindeer-hide drum decorated with symbolic animal figures.

Tubiakou's Spirit Flight

A Siberian shaman adapts his ancient profession to modern times

Text and photographs by Alexander S. Milovsky

They still tell how, in the 1920s, the man called Jukodeh became respected as the greatest shaman of the Nganasan people. He had agreed to heal his prospective father-in-law, who was very ill, but first felt called upon to test his powers on himself. So Jukodeh cut his own side open with a knife, licked the blood off the blade, extracted his spleen, buried it in snow, and ate it raw and frozen, as the villagers in this area of northern Siberia often eat reindeer meat. No one I met doubted that he actually performed this feat, although I did not speak to any witnesses. Even though the man whom he had come to heal died, Jukodeh was approved as a great shaman and married his patient's daughter.

I had come to Ust-Avam, in the Siberian tundra, to see Jukodeh's son Tubiakou Kosterkin, who is regarded as a great shaman in his own right. I came not only as a journalist but also as a patient suffering severe back pains. Although a shaman's talents are usually passed down only to every second generation, grandfather to grandson, Tubiakou, at sixty-seven, is undisputed as his people's greatest living shaman. The Nganasan ethnic group, one of the numerically smallest in the world, live in the Taimyr (Dolgano-Nenets) National District in Siberia's extreme north, well within the Arctic Circle.

Tubiakou informed me that his powers had declined in the past few years because he had ignored a serious professional obligation: to perform at least four seasonal rituals yearly, including the Clean Chum Festival on the vernal equinox, the most important of all. A *chum* is the portable, wigwamlike dwelling of North Siberian peoples; during the annual ceremony, a shaman is expected to purify his specially built chum, while pleading with the spirits for good hunting and protection of the tribe's reindeer from wolves. He also inquires if any of his recently deceased clansmen need anything in the nether world and learns important information about the group's future, including the sexes of children soon to be born.

Tubiakou believes that for not performing the ancient ritual, the spirits punished him with the illness and death of his wife, whom he was powerless to save. When she died in 1986, he suffered a severe depression, gave up his shamanic duties, and even sold his unique ritual dress with all its appurtenances to the Dudhinka museum. But a shaman cannot simply walk away from his calling without permission from the spirits of his shaman ancestors. Eventually, he realized that he must take up his profession again and asked for the return of his magical clothing. Museum curators prized it as a priceless ethnographic rarity, however, and refused to give it back. Only after a sympathetic ethnographer interceded did the Russian Ministry of Culture finally agree to lend the clothing to Tubiakou for important ceremonies.

The outfit is basically a parka, a shirtlike, collarless garment made of reindeer suede, with an iron chain sewn onto its back. During deep trances, the shaman's helpers hold the chain so they can pull him back from his dangerous journeys to other worlds. Both the shirt and its breastpiece

are profusely studded with copper, iron, and carved bone figures that play well-defined roles in the proceedings. The double-headed copper navel, or *kin,* protects the shaman's belly, and its iron geese command the elements of earth, air, and water, assisting in his magical flights.

Sequined ribbons attached to a headband cross one another at the top of Tubiakou's skull, supporting the iron antlers of the Heavenly Deer and a grooved copper headpiece, from which is suspended a dense fringe of suede strips. These hanging strips completely hide his eyes and are meant to protect people from the gaze of the powerful spirits that will enter him during the rite. Fur shoes and fingerless mittens complete the ensemble. The shaman uses a traditional frame drum, whose mammoth-bone clapper is sheathed in *camoos,* the fine fur from a deer's legs.

Details may vary from clan to clan, but a shaman's dress always resembles the ancient bird-beast with which his spirit merges. When he flies right between the spread legs of the white goddess in the upper world, she dare not devour him because he is disguised as the oldest of the ancestor spirits.

When my interpreter, ethnographer Yuri Simchencko, and I went to Tubiakou for my healing session, all the shaman's paraphernalia was laid out. Clad in his elaborate gear, Tubiakou was smoking his pipe and sitting on a deerskin at the back of the ritual chum, with his helpers squatting at his sides. First among them was his brother and chief aide, Boris, who acted as the intermediary and "interpreter" between us and the spirit world. His son Leonid, daughter Nadezhda, and nephew Delsimjaku Demnimeh sat motionless beside him, enveloped by bluish smoke from the central fire.

What made the picture even more surreal was a paper icon of the Virgin Mary hanging from a pole, close to a wooden carving of an ancestral nature spirit. Her image had been placed there because the patient—myself—was of the Christian faith. Saints have been highly regarded in Taimyr since the seventeenth century, when Russian pioneers first ventured here, bringing their icons with them.

Missionaries believed that the shamans probably had the power to cast out minor demons, and they raised no objections so long as the practitioner sought to ease suffering and neither served the devil nor went against the Almighty. Many Khants, Mansis, and Dogans have been baptized over the past few centuries, but shamanism and its ancient nature–spirit religion have managed to survive alongside Christianity in Siberia.

The Communists were not as tolerant as the missionaries. Many locals tell blood-curdling stories of how shamans were ruthlessly killed during the government's attempt to wipe out their religion. In one infamous incident, officials lured several shamans into a house for a parley, then locked the doors and burned them all

Tubiakou beats on the sacred drum's rim to summon his helper spirits, left, while a Christian icon and Nganasan nature deity gaze down from their place of honor on a chum pole. Below: Before his spirit flight, symbolized by the iron goose he wears, the shaman's helpers anchor him to the central pole. If he is drawn too deeply into the spirit worlds, they believe they can pull him back with the chain.

alive. Tubiakou spent two terms in one of Stalin's concentration camps for belonging to a "seditious profession"; only recently has this fierce persecution ceased.

Typically, shamanic rites induce a state of ecstasy, accompanied by singing and the shaking and beating of frame drums. Similar ceremonies are performed among the Inuit, Native Americans, and many peoples of Africa and North and East Asia. In some places, shamans are not only physical healers but also keepers and guardians of the spiritual and cultural heritage of their clan or tribe—an important function among peoples who lack a written language. Tubiakou is a living repository of orally transmitted myths and stories, which he has recorded on tape for ethnographers and folklorists. The ancient Nganasan epics—the rich legacy of a people who now number barely 900 men, women, and children—turned out to exceed twelve times the combined length of the *Iliad* and the *Odyssey*.

On these tapes, Tubiakou explains that the universe consists of three spheres: the upper and middle worlds and the lower one, which is not necessarily subterranean. The world began when Earth Mother, or, more precisely, World Female, was an indivisible part of another creature, named Ice Mother, personifying cold and the nether world. When Sun Mother, the third creator, came close to the other two, her warm rays divided them, creating two lesser spirits, Water Mother and Gods' Mother.

Gods' Mother is conceived of as a huge, naked woman reclining, somewhere in the middle world, with her legs spread wide. Water flows constantly from her genitalia past her knees, which, like cliffs, divide the stream into three channels of life. All the subsidiary gods were begotten by this woman and began to run the world. In so doing, some remained above, while others descended and became intermediaries between all living things and the spirit of Cold. Tubiakou communes directly with seven of them: three spirits of the lower world, three of the upper, and one of the middle. He also addresses Daibango, the tribe's patron god.

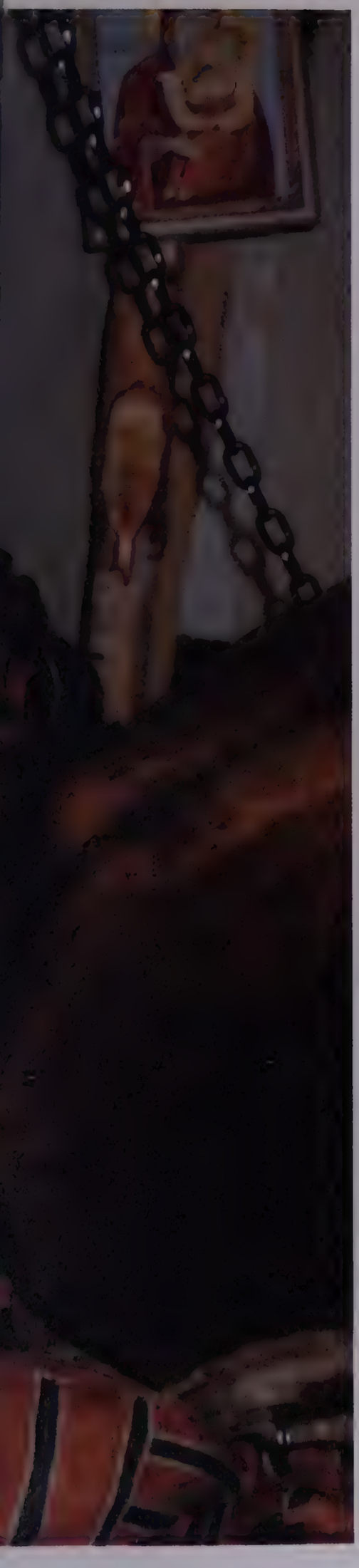
A shaman inherits some of the spirits from his predecessors and contacts others on his own. Tubiakou holds that his shaman soul came from his grandfather and

that some of the spirits came from his father, which is unusual.

Gods' Mother places a special soul into a shaman, who may then become the founder of a shamanic family. When he attains a certain age, helper spirits, or *jamadas,* come to him as intermediaries between himself and the lesser gods. Tubiakou has twenty-one of them, a sacred number. Spirits torment future shamans, knocking out of them all properties that make them ordinary. This reshaping process may be difficult, long, and painful. Developing shamans often fast for long periods and may live as hermits on the tundra for several months, sometimes even years, during which they often fall ill. Tubiakou's father, Jukodeh, told people that one of the spirits, the ironsmith, discovered that he had three redundant sets of eyes and ears, which allowed him to see and hear everything that went on in three places at once. Jukodeh tried to argue with the spirit, maintaining that he had no extra body parts, but was finally compelled to realize that he could, indeed, monitor what was happening on three planes simultaneously during his ritual trances.

Before their initiation, aspiring shamans pass examinations in the presence of their clansmen: they look for and find hidden objects while blindfolded, sense holes and bushes in their path, and in the case of some Siberian peoples, lick red-hot metal with their tongues. Tubiakou told me that if a man could not cut himself open with a knife in front of his clansmen to prove his supernatural powers, he had no right to be a shaman.

The journey to the spirit world is very difficult and dangerous, and the shaman's soul may be intercepted by spirits who will not let it return. If he is not tough enough to best the spirits, his patients may be killed by them. The Nganasans told [illegible] Galina Gracheva about a [illegible] named Juare, who once failed to control his spirits, and some people died after his rites. Tubiakou had assured me that all forces in the inner worlds were neutral and that there were no evil or kind



Sweating and gasping from the exertion, the sixty-seven-year-old shaman cajoles powerful spirits into helping his client. His rich ceremonial garb includes a bear-paw bracelet and iron deer antlers contributed by kinsmen.

spirits any more than there were white or black shamans. He admitted that he had occasionally called the spirits against evil people who had killed or robbed someone of his clan, and that those people had died. But he had done such things strictly in defense, not as a malicious abuse of his powers. During dangerous contacts with spirits, all the shaman's strength is required to avert accidental fatalities or other disasters, which is why the ceremony often exhausts him. Jamada helpers lead the shaman through their lands, where more powerful spirits dwell—areas that correspond mystically to the earthly territory of his clansmen.

Shamans used to have three special travel costumes for venturing into the upper, lower, or middle worlds. A shaman visiting a woman having complications following childbirth, for example, dresses in the lower earth costume, because such healing would require a visit there to trace the patient's past and find the source of her problem. Performing rites in the upper world requires a drum with an appropriately colored wooden frame. The lower world, on the other hand, requires one made of mammoth bone, because all the spirits there are mammothlike.

Shamans used to heal only their clansmen or relatives, but in the nineteenth century it became part of professional ethics to help anyone in need. Jukodeh said the spirit who gave him his supernatural powers constantly admonished him: "If you meet an orphan or a widow, try to help them. Do not scorn them and never say they have no kith and kin. Do not pass them by, or I will cut off your breath."

An ordinary man cannot communicate with the upper forces of nature, although he can address them directly by sacrificing a deer. With the shaman's help, his request will certainly reach the ears of the deity, for he can summon his jamada helpers, who take him to one of the spirits. They in turn may appeal to such superior creatures as Gods' Mother or Sun Mother, who can answer all questions.

Why would a spirit deign to help a shaman? Spirits need food, and he feeds them with various sacrifices. To get their attention, the shaman traditionally burns deer fat in the ritual fire, but Tubiakou prefers to offer vodka. He takes a few swigs himself, rather than pouring it directly into the flames. Ethnographers have reported that some Siberian shamans have traditionally eaten hallucinogenic mushrooms to alter their consciousness, but the only mind-altering substance I observed was Russian vodka. Tubiakou began the new practice after his abstemious father died. Life had been rearranged in recent years, he explained: In former times, women would never think of stepping over a sleeping husband's head or even walking over his property. Now people live in houses where women walk about on upper stories over the heads of men. When the world order changed, the spirits' diets changed, too, and they commanded Tubiakou to drink vodka during the ceremony.

The sacred drum was tuned by Tubiakou's son Leonid. After smoking the pipe for a while, Leonid seized the drum and jiggled it about over the fire. Now and then he spat on the tightly stretched skin, spreading his saliva with the clapper, and tested the sound. When the tone was what he wanted, Leonid began rhythmically striking the stretched skin with the clapper, summoning his father's spirit helpers.

Similarities between Siberian shamans' frame drums and those of North American Indians suggest that they may date back thousands of years, prior to the ancient migration from Asia to America across the Bering land bridge. Among the Nganasans, the drum is associated with reindeer. Four forged iron staples, called the legs, hold the stretched skin of a wild male reindeer to the inner side of the frame. Beads, known as teeth, are sewn onto the skin.

After several minutes of drumming, Tubiakou acknowledged that all his spirit helpers were present and issued the ancient call, expressing his desire to meet with them. "Ta-ma-ny," he chanted, stretching out the sound, while four of his clansmen repeated: "Ta-a-ma-a-ny-y."

Calm, motionless, and exhausted, Tubiakou has "landed" back on his deerskin; now his helpers can safely unfasten the chain, signaling that the dangers of his spirit flight are over.

My ethnographer friend Yuri Simchenko, who had known Tubiakou for more than twenty years, indicated that I must now put my problem before the shaman and his spirits. According to a Moscow doctor, I had radiculitis, a chronic inflammation of the spinal nerve roots. Not without misgivings, I knocked on the drum's rim with a stick and begged, "Please, relieve me of my radiculitis."

Tubiakou struck his drum vigorously with the clapper, lowered the fringe of suede strips over his eyes, and "took off" on his mystic flight, with all his twenty-one spirit helpers.

The *kamlaniye* rite had begun. Tubiakou always begins and ends it with his personal song about a reindeer doe, which Gods' Mother had taught him. Altogether, there would be seven songs. While the shaman sang incomprehensible words, his brother immediately translated them for the summoned spirits.

I had been warned that I could be helped only if I treated the proceedings with complete respect and allowed myself to suspend disbelief. In this mystical atmosphere, convinced that many had been healed in this way, I did not find it difficult to be receptive.

Tubiakou sang on and on. From time to time, his melodious voice seemed to be interrupted by intrusive otherwordly screeches and animal bellows, the exclamations of the helper spirits. Tension in the chum built up as the drumbeats became more intense. Tubiakou was coming closer and closer to the first major spirit, the eight-legged Bydytangu. The shaman's son poured a glass of vodka, and Tubiakou drank it quickly; then he knocked a little stick against the edge of the drum, asking the spirit who had just been fed to help him. Since this spirit was apparently unwilling or too busy to assist with a stranger's medical problem, Tubiakou again knocked on the drum to summon his helpers, rose to his feet, excitedly hammered on the drum, and began leaping about. Leonid nimbly seized the chain on his father's back and, securing it around the pole of the chum with his uncle's help, hung on to it. Tubiakou was being dragged deeper into another world, but his human helpers and the chain anchored him in this one. Finally, on his magical flight, Tubiakou saw "land," where the two-faced one, a spirit he had inherited from his father, reclined. Half of its face was calm, while the other half burned with anger.

The two-faced one evidently had no desire to dig about in my past, looking for the origin of my back problems—perhaps a boyhood swim in ice-cold water. Tubiakou pressed him and began to beat the frame drum frenziedly as he jumped about, half crouched over. Now he encountered a more powerful spirit, the Bear Khenko. Suddenly, the shaman began to imitate a bear's way of walking, and his song suggested its roar. "Hello, it is me, Uncle," Tubiakou said to this spirit.

"A-o-u, o-a-u! Antyna, man-ty-na, haku-ai!" the bear growled in reply.

Tubiakou spun around three times, then sat down, while Boris poured some more vodka. A swig, and the spirit entered the shaman. Black Bear questioned me through him, trying like a tracker to trace my life's path.

"Last year you had three big problems at your job. You settled two of them, but failed to settle the third. Am I right?" He asked a few more personal questions, and suddenly I felt the pain in my neck recede and the tension drain from my aching muscles. I turned my head without the usual effort or pain, and my shoulder no longer ached from carrying my heavy bag of photographic equipment.

After thanking the spirit and treating him to another shot of vodka, Tubiakou shook, jumped about, then "landed" safely back in the chum. Lowering himself heavily onto the animal skins, he brushed the fringe from his eyes. Sweat was streaming down his face and his whole body showed the fatigue of a great effort. He lit his pipe and pulled on it, while his human helpers sat motionless again. The Virgin Mary looked down upon me with empathy from the post of the shaman's chum. □

Monkeys with Inflated Sex

As breeding season approaches, some male squirrel monkeys grow alluringly plump

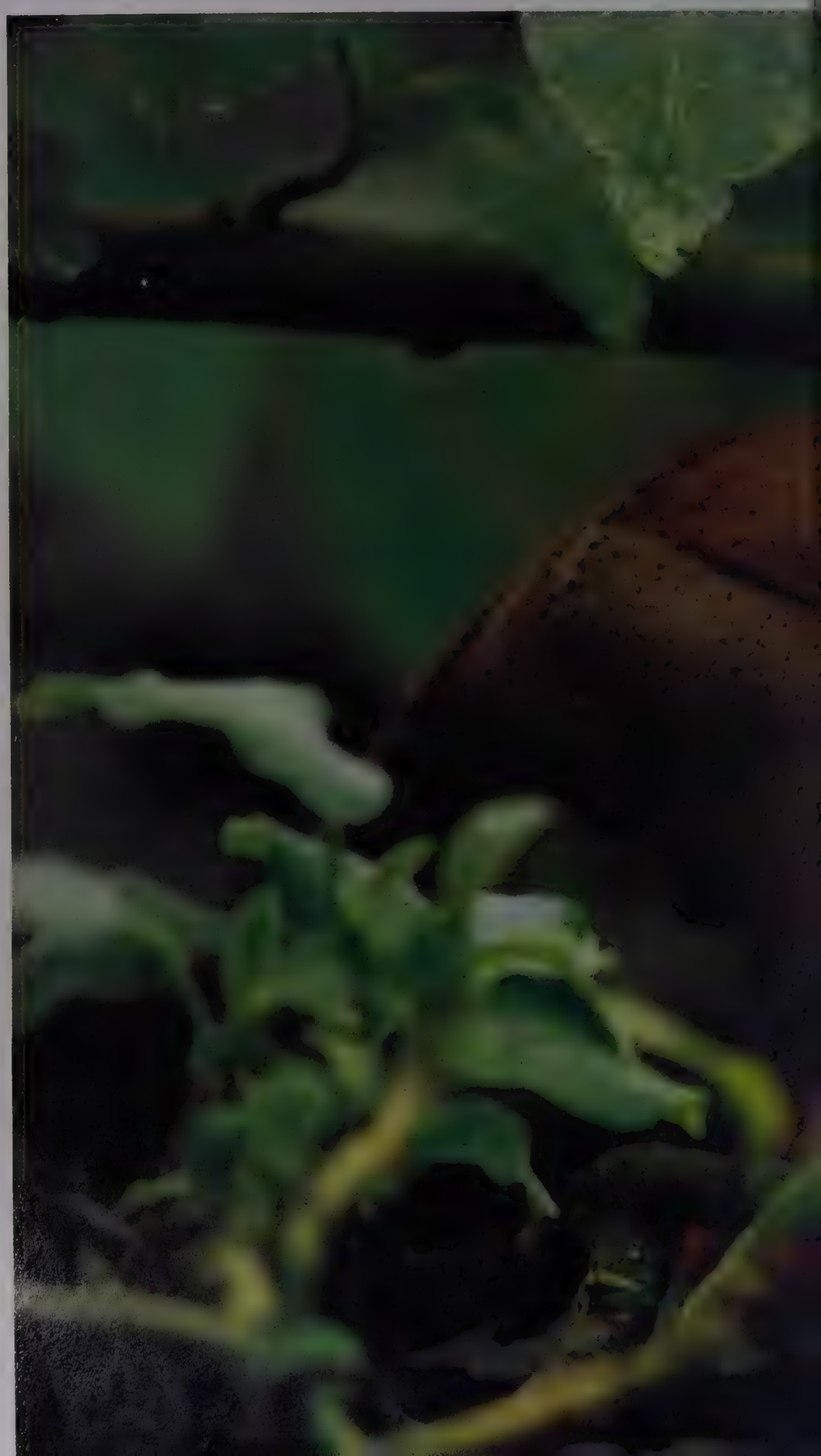
by Sue Boinski

It was late August, and in Parque Nacional Corcovado, on the Pacific coast of Costa Rica, squirrel monkey mating season had finally begun. Ignacio, the largest of five adult males in the forty-member troop I was studying, woke from a midmorning nap in a *peine de mico* tree and scanned the nearby foliage for caterpillars. As I watched him, I was amazed at the transformation he had undergone. During the previous three months, his body mass had increased by about 25 percent. The increase was largely in his upper torso, but his testes had also more than doubled in size. This temporary, seasonal enlargement of his body tissues so encumbered Ignacio that he had acquired a somewhat rolling gait reminiscent of John Wayne's.

As Ignacio awkwardly made his way to the ground to pluck a leaf-mimic grasshopper from the litter, five adult female members of his troop spotted him and gave chase. These females had been searching for him, prowling the two acres of rain forest in which troop members were dispersed that afternoon. Ignacio fled but soon relented. During the next twenty minutes he engaged in his third and fourth mating of the day with the female that caught up with him first.

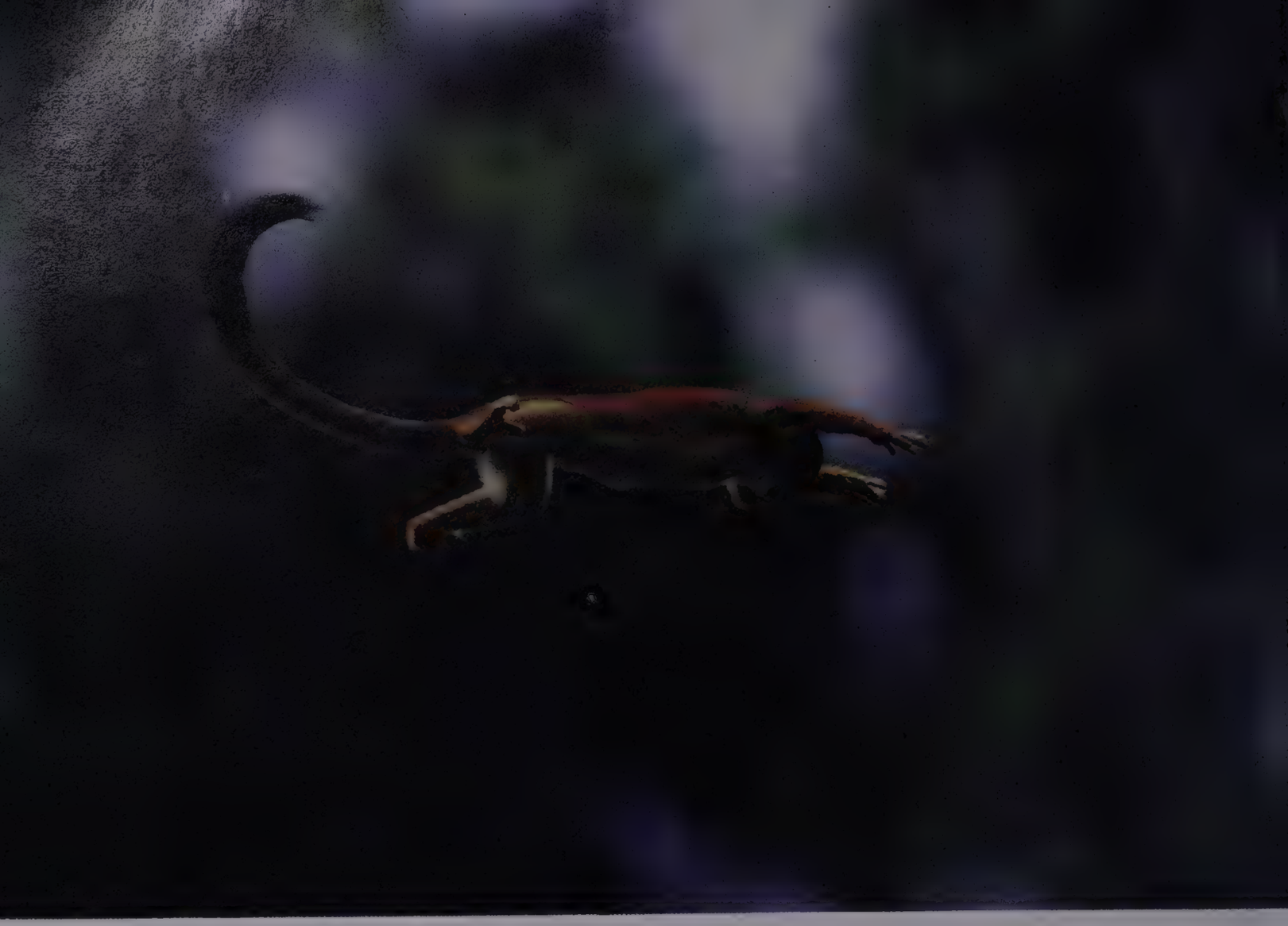
By late afternoon, Ignacio was again fast asleep in an out-of-the-way clump of vegetation. He had already mated at least eight times that day. Rosa, who had not yet been successful in her pursuit of Ignacio, approached to within eight inches, calling vociferously. She nuzzled his face, then turned around and positioned her genital region so that it touched his face, but Ignacio did not even open his eyes. When that maneuver failed, she abandoned him. I followed her until she found Pedro, a male [illegible] swelled to become the second [illegible] in the troop. Within thirty sec[illegible] approach, the two mated.

[illegible] between Ignacio and the [illegible] was one of many scenes I wit[illegible] indicating that sexual receptivity [illegible] squirrel monkeys was un[illegible] synchronized and that females strongly preferred to mate with the largest



Appeal

Adult male South American squirrel monkey
Gerry Ellis; The Wildlife Collection



male around. (Ignacio was involved in 70 percent of the copulations that season.) What I saw over the three breeding seasons consistently confirmed that female choice is very important to the squirrel monkey breeding system and that smaller males generally get their opportunities to mate only when large males reject females' solicitations.

Although squirrel monkeys are widespread throughout the tropics of South America, the small Central American population is extremely endangered. The species used to be common in the Pacific lowlands of Panama and Costa Rica but now seems to be extinct in Panama and nearly so in Costa Rica, because of extensive deforestation for agriculture and timber and a now-defunct live-animal trade. In Costa Rica the recent upsurge in tourism development on the west coast is rapidly eroding the monkey's remaining Central American habitat. The roughly 150 square miles of Corcovado is home to perhaps 450 squirrel monkeys.

I had come there to study many aspects of squirrel monkey behavior, including vocal communication and foraging, but pressing most persistently for explanation was the species' unusual annual reproductive cycle. I knew that numerous studies in primate laboratories and a few brief field observations had established that these monkeys differ from all other primates with respect to mating and birth. First, all known wild squirrel monkey populations (and well-established captive groups as well) have unusually predictable mating and birth periods, which seldom exceed two months' duration and which are separated by five and a half month intervals. Each female usually mates for just one or two days of each breeding season. When the time comes for the babies to be born, many of the troop's females give birth within a week or two of one another. Several mothers may give birth on a single night, and many of the rest follow suit within a few weeks.

The second notable feature of squirrel monkey reproduction is the seasonal enhancement in male body size. During most of the year, males cannot be distinguished from one another on the basis of size, but two to three months before the breeding season, males start to swell up as water is deposited between the skin and muscle layers of the shoulders, back, and upper arms. Neither increased food intake nor decreased activity causes this size increase nor is it related to reproductive ability, for males are fertile year round.

Laboratory investigations of animals from a South American squirrel monkey population have documented the physiological mechanisms (apparently unique to the genus) that underlie the enlargement phenomenon. The hormone testosterone is converted to estrogen, a female reproductive hormone. The more testosterone a male has, the more estrogen he produces and the more he enlarges. The swelling is brought on by an altered water balance similar to that causing many women to swell toward the end of their menstrual cycle. Yet to be elucidated is how this seasonal enlargement is triggered in the wild, where it anticipates estrus by one or two months.

Male size hits a peak during the height of the breeding season, strongly suggesting that the swelling may be a product of sexual selection. Darwin developed his theory of sexual selection to explain the evolution of sexually dimorphic traits, such as large antlers and extravagant plumage, that are of little obvious utility in

Gregory G. Dimijian; Photo Researchers, Inc.

A Costa Rican squirrel monkey leaps from tree to tree, left. Below: The martenlike tayra is one of the monkey's many predators in the forests of Costa Rica.
Art Wolfe

daily life. He argued that these traits evolved because they increased an individual's mating success, through either intrasexual competition (usually in the form of male–male contests over access to females) or intersexual mate choice (usually female discrimination among males).

My breeding-season observations led me to think that female choice, not male competition, lies behind the evolution of seasonal swelling in squirrel monkey males. In my study population, juvenile females leave their natal troops and eventually join other groups. But males seem to stay at least for the four or five years it takes them to mature sexually. At that point they either wait until they succeed into the reproductively successful position held by a few adult males in their own troop or go off with the others in their birth cohort and try to oust the breeding males of another troop. Within their own troop, however, males are peaceable. Males never force females to copulate, and I never saw males within the same troop compete among themselves, even during mating season. In fact, Costa Rican squirrel monkeys are among the most egalitarian primates in the world, unusual in this respect even when compared with their South American counterparts. No dominance hierarchies are discernible, and in my study troop, the closest that males came to physical competition was their frequent rough-and-tumble play wrestling. (Studies of South American captive squirrel monkeys, however, show that the degree of male enlargement correlates not only with testosterone levels but also with social dominance. It is possible that in their bouts of play, the monkeys in my troop are establishing some kind of subtle hierarchy.)

To investigate what lies behind female choices, I had to find out whether largeness in males signals any hidden genetic or social advantages and why the females' periods of sexual receptivity are so synchronized. This required getting to know the monkeys well. In Corcovado, thirty-five to sixty-five squirrel monkeys make up a troop. Troops never subdivide into separate foraging groups, but members may disperse over an area of more than three acres and often engage in very different activities. Some may be searching dead leaves for insects, others foraging for fruits, and still others resting or playing. After my first year, I had no difficulty keeping up with a traveling troop (unless they entered a particularly nasty part of their range filled with dense patches of six-foot-tall terrestrial bromeliads). But in the beginning it was challenging to follow these often rapidly moving monkeys. I had to learn to focus on one individual and not be distracted by the movements and activities of its neighbors. Moreover, as their name suggests, the animals are small. Outside of the breeding season, females weigh about twenty ounces; males, twenty-eight.

One of my first goals was to find a way of identifying the individual animals in my main study troop. The squirrel monkey's looks are striking; its masklike white face contrasts sharply with its black muzzle and black cap of fur, and its golden or bronze-colored long limbs and tail often seem to glow in the sun. Age and gender in the troop are easy to distinguish because of marked differences in genital development among age groups. Given enough time, I could distinguish individuals by their unique scars, tail kinks, facial discolorations, or hair whorls. But picking up these subtle cues was often impractical when the troop was traveling and the ani-

Wolfgang Bayer

Too big to be carried underneath its mother's belly, this South American squirrel monkey baby, right, will spend much of its first few months traveling around on her back. Below: A juvenile female explores a laurel negro *tree in the Costa Rican forest.*

Roger Tidman

mals were high in the trees. The marking technique I devised was of great help in studying individuals in the field. It was easy, albeit messy, to apply permanent black dye with a squirt gun; it took me weeks to learn not to squirt into the wind. The animals did not react adversely to being squirted; many looked up as though it were raining.

Fortunately for me, Corcovado squirrel monkeys tend to stay only fifteen to thirty feet above the ground most of the time. Also, unlike squirrel monkeys in some other areas, they sleep in the same tree for months on end, so even if a troop eluded me during the day, I knew where to find it the next morning.

In Corcovado, squirrel monkeys use a mosaic of habitats, including primary forest, selectively logged forest, and second-growth forest (from small farms abandoned when the park was created in 1975). Over the course of 300 feet, the habitat may change from stands of five-foot-tall, bananalike *platanillo* to forests with 120-to-150-foot canopies. Squirrel monkey troops can exploit these different types of forest because the insects they feed on, such as caterpillars and grasshoppers, can be found wherever there are leaves. The monkeys also eat soft, berrylike fruits such as figs.

Annual rainfall in Corcovado is about 200 inches, most of it falling during an intense wet season from September to mid-December. In contrast, January to late April is a time of very little rain, usually less than ten inches total. The ecological contrast between these two periods is comparable to that of winter and summer in temperate climates. To document how the squirrel monkeys are affected by differences in the two seasons, I carefully noted the ups and downs in their foods each month at locations scattered randomly throughout the site. I found that during the wet season, populations of arthropods—insects and spiders—crash for two reasons. First, little new foliage (the food of many of the insects eaten by squirrel monkeys) grows during this season. Second, the heavy rains simply wash many arthropods off the leaves. The more rain, the more time squirrel monkeys spend looking for food: during the wet season, they devote more than 70 percent of each day to obtaining food; this figure falls to 40 percent during the dry season.

The ups and downs in food supply surely affect the timing of reproduction:

babies would not survive if born when food is scarce. But seasonal differences in food could not fully explain the tight synchrony of births so early in the dry season. After all, births are tightly clustered within a six-week period between February and April, but peak food availability is in May and June, and food is still relatively abundant until September. Since babies are usually weaned when about four months old, there is a broad window of time in which they can be weaned without launching them in a lean season.

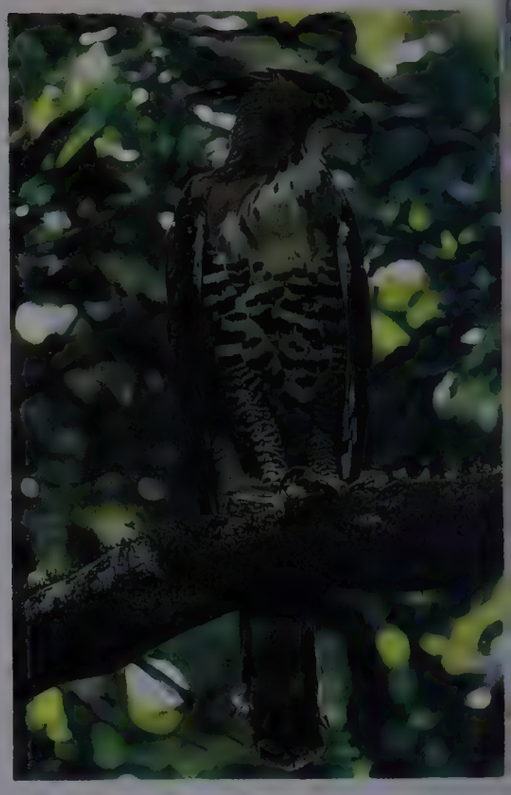
I then looked at the role of the monkeys' predators. I suspected—as it turned out, correctly—that the conspicuous way groups of these small animals moved through their large home ranges made them prime targets for eagles, hawks, and falcons. During my three years in Corcovado, I saw more than forty attacks by raptors, five of which were successful. The monkeys are extremely vigilant against such attacks, frequently interrupting whatever they are doing to crane their heads back and scan the sky. Whenever a monkey spots a raptorlike object, it gives a distinctive, high-pitched alarm peep and dives for cover, as does every other troop member within hearing range. The monkeys err on the safe side in giving alarms, calling at the first hint of possible danger and taking a second look only once they have found a protected position. Erring on the side of caution, the monkeys peeped not only in response to eagles and falcons but also to small airplanes, falling branches, and even big leaves.

In early February I began to see signs that predation might indeed play a crucial role in the monkeys' reproductive cycle. One morning, I came across two females huddled together so closely that they were rubbing against each other. I was startled because for most of the year, female squirrel monkeys in Costa Rica have essentially no social bonds. They pass their time dispersed throughout the troop, ignoring one another and everyone else, except during their brief, tumultuous estrus. Even during pregnancy, when their silhouettes

Gregory G. Dimijian

Birds of prey, such as the ornate hawk-eagle, below, are a threat to all squirrel monkeys and may pull babies from mothers' backs. Right: Except during breeding and birthing seasons, squirrel monkeys are not very social and usually forage independently within the troop.

Craig J. Flatten



alter radically, their social behavior, or rather, their lack of it, remains unchanged. I have never seen one squirrel monkey groom another, and mothers largely ignore even their own babies once they reach four or five months of age.

I was intrigued, therefore, to see the two females, Gladys and Carmen, so intimate. As I looked, I noticed that they seemed to be anxious, spending a lot of time staring into the sky and swiveling their heads around. Eventually, I realized that each was carrying a scrawny baby on her back. Within two weeks of my seeing Gladys and Carmen and one more female with newborns, nine more of the fourteen pregnant females in the troop gave birth. Five babies were born on one night and four more within the next seven nights. One female gave birth a month after the birth peak; another, two months later. Immediately after parturition, each female underwent the same dramatic change in behavior as had Carmen and Gladys. Until the babies were three months old, mothers tripled the amount of time they were vigilant, and they stayed in close-knit groups for all activities.

There is little question in my mind that the threat of predation accounted for the females' behavior. Seven of the fourteen babies born in the troop had disappeared by April. Circumstantial evidence suggests that they were eaten. The amount of time that raptors were either directly above or near the troop rose from 2 percent in January to 10 percent in February, when the babies were popping out like popcorn. Eight times I saw collared forest falcons try to grab a baby right off its mother's back; each time, the falcons were mobbed and driven off. Some of the mothers that lost their babies had scratched and bleeding backs like those of monkeys I have seen attacked by falcons. Several other species of birds also launched attacks at me. Once I watched as two chestnut-mandibled toucans glided into a cluster of mothers and scooped up two babies. When a baby disappeared, its mother immediately returned to her former solitary ways.

Assuming that increased group vigilance saves more babies' lives than does individual watchfulness, birth synchrony may also have evolved in response to predation pressure. Supporting this hypothesis are my preliminary data indicating that babies born before and after the birth peak are more likely to be killed by predators. The rate of survival is greater when several mothers are present. In order to benefit from the increased vigilance of a group, the otherwise unsociable females must raise their young during the same short period, and for that to happen, they must mate more or less at the same time. In the mating season, male squirrel monkeys face a horde of females with overlapping estrous periods. Unable to physically dominate them or to defend them from other males, male squirrel monkeys have no choice but to wait until females select them as mates.

And there is no question that the females prefer to mate with the swollen males. But why? Is seasonal size enhancement a signal of quality? If so, what are the criteria? Males do not control access to food patches; the insects they eat are scattered throughout the forest and cannot be monopolized. Nor can male enlargement deter predators when it counts most: males are most enlarged during mating season, not after babies are born.

Two features of these males, however, do stand out as significant. One is that the most enlarged males are the ones that have lived in the troop for long periods, often at least three years, regularly resisting challenges from outside males that try to oust them. The other is that the most enlarged males are consistently vigilant throughout the year and most likely to intervene directly when babies or other troop members are threatened. These reproductively successful males spend about 5 percent of their time actively on the lookout for trouble, which is two to four times more than that of adult females, except those carrying young babies. In one eleven-month period, I observed twenty-four instances of males—usually those that became the most enlarged during the breeding season—retrieving and aggressively defending babies and subadults from such potential predators as tayras, opossums, spider monkeys, coatis, collared forest falcons, crested eagles, and snakes. The role of defender exposes a male to serious risks. I once witnessed a crested eagle snatch up one of a group of males that were mobbing it. But the risks may be worth it: the baby a male saves may well be his own.

From the females' point of view, the attractiveness of big males may lie in their capacity to defend the troop. Or females may be "attempting" to select good genes for their offspring; perhaps, for example, the largest males are more resistant to parasites. Possibly, large size confers no survival advantage at all; males selected for largeness may simply produce large sons, which in turn will also be attractive to females—an example of runaway sexual selection. I sometimes wonder if I will ever successfully tease apart all the possibilities. As I watch the females frantically chasing after the big males, however, I realize that the monkeys suffer from no such doubts. □

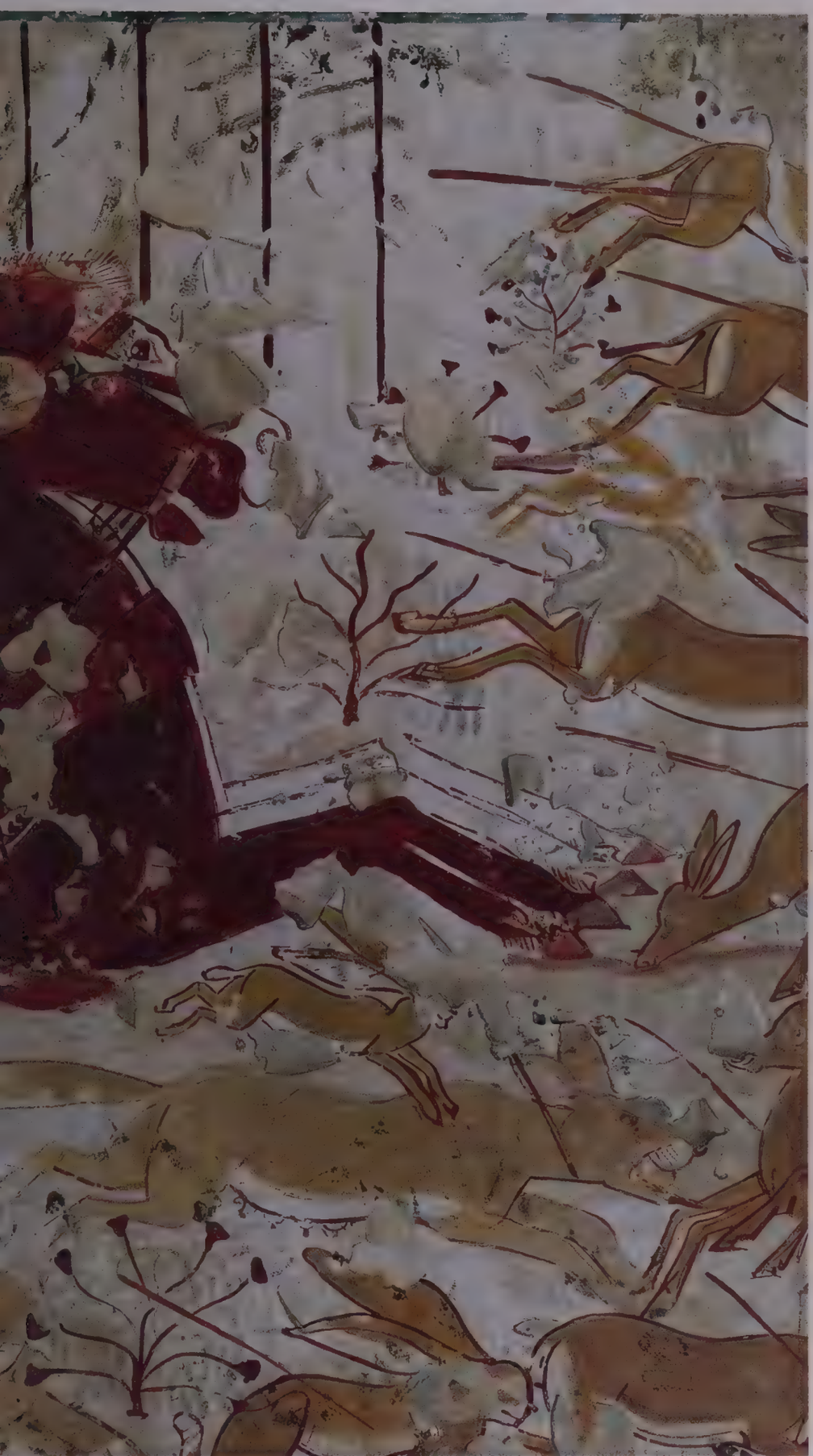
A copy of a wall painting from the tomb of Userhet, in Thebes, depicts a hunt during the reign of the pharaoh Amenophis II (ca. 1438–1412 B.C.). The chariot was a legacy of the Hyksos, invaders from the northeast who ruled Egypt from about 1650 to 1540 B.C.

Egyptian Expedition of the Metropolitan Museum of Art, Rogers Fund, 1930

Old Sports

The Olympic Games were not the earliest athletic rituals in the eastern Mediterranean

by Allen Guttmann



Every four years at Olympia, the athletes of ancient Greece paid homage to Zeus by demonstrating their *arete,* their excellence of mind and body. According to Hippias of Elis, the nearby city-state that organized the competitions, the Olympic Games began in 776 B.C. with a simple footrace, and other events were subsequently added. But the list of victors Hippias compiled, sometime about 400 B.C., exaggerated the age of the games, apparently to aggrandize the glory of his native city. Plutarch admonished that Hippias "had no fully authoritative basis for his work," and historians now believe that the games began, with as many as five different sports, about 600 B.C., more or less at the same time as the sacred games at Delphi, Corinth, and Nemea, which rounded out the four-year cycle of Greek athletics. (Isaac Newton anticipated modern scholars, estimating the games' later origin by recalculating the duration of royal reigns and accurately dating eclipses referred to by ancient astronomers.)

The true precursors of the sixth-century games remain elusive, but we do know that the Greeks were not the only people of the eastern Mediterranean to emphasize athletic ritual as a religious and political statement. In ancient Egypt, for example, from at least 3000 B.C., physical prowess was a necessary sign of a pharaoh's fitness to rule. As a representative of divinity on earth, his role required him to maintain order against the forces of chaos. A pharaoh commemorating the thirtieth anniversary of his enthronement would formally prove his fitness by executing a ceremonial run in the jubilee known as the Festival of Sed. The course, from one mark to another and back, symbolized the boundaries of the kingdom he protected. The earliest known turn markers, at the pyramid of Djoser (ca. 2600 B.C.), lie about sixty yards apart.

There were numerous other occasions for a pharaoh to display his strength and stamina. Inscriptions and reliefs testify to almost superhuman demonstrations of hunting skill, events that may or may not have actually occurred. Tuthmosis III, for

example, one of the monarchs of the Eighteenth Dynasty (1552–1306 B.C.), boasted, "In an instant I killed seven lions with my arrows." Similarly, he and several other monarchs of that dynasty were said to have so mastered the composite bow (made of hardwood, softwood, and horn) that their arrows were able to transfix sheets of copper "three fingers thick." (Modern attempts to replicate this feat have failed.) The pharaoh had to be seen as the mightiest archer, most successful hunter, and swiftest runner. An American president can lose a tennis match without unleashing the forces of chaos, but Tuthmosis III was required to surpass all mortal achievements.

In the biography of Cheti, prince of Siut, who lived during the Eleventh Dynasty (2134–1991 B.C.), we read that "he learned to swim together with the children of the pharaoh." But despite the central role of the Nile in Egyptian life, there is no evidence that the pharaoh was expected to demonstrate his prowess at swimming. Or perhaps Egyptian artists considered the physical movements too undignified to show in a representation of divinity. There is, however, an inscription telling of the amazing boating exploits of the Eighteenth Dynasty monarch Amenophis II, who was said to have steered his "falcon ship" for three *itrw* (about 18.6 miles), when others gave up in exhaustion after a mere half *itrw*. And according to Egyptian legend, the gods Horus and Seth, both of whom claimed the right to rule the universe, agreed to settle their dispute with a diving contest.

If the quantity of visual evidence is any indication, wrestling was among the most popular Egyptian sports. Murals discovered in the eleventh-century tombs at Beni Hasan depict nearly every hold known to modern wrestlers. Although the sport has a religious character in many cultures, including those of Africa south of the Sahara, for the ancient Egyptians it seems to have been a purely secular contest. A pharaoh thrown roughly to the ground would have been a terrifying portent of disaster.

The pharaohs most celebrated for their athletic achievements were the martial monarchs of the Eighteenth Dynasty, especially Tuthmosis III, Amenophis II, Tuthmosis IV, and Amenophis III. These were the immediate successors of the Hyksos, a seminomadic people whose warriors swept from the northeast into the valley of the Nile about 1650 B.C. Their war chariots spread terror among the Egyptians of the time, for whom this was an unknown weapon. For more than a century, the Hyksos usurpers ruled Egypt; once they were expelled, more emphasis than ever was placed on the pharaoh's physical prowess. Even Queen Hatshepsut, an Eighteenth Dynasty monarch who ruled as if she were a man, had to prove her fitness with the time-honored ceremonial run. A relief discovered at Karnak de-

Art Resource, New York

Each wearing one glove, young boxers, left, spar in a fresco from the island of Thera. Outposts of Crete's Minoan civilization, the settlements on Thera were destroyed by a cataclysmic volcanic eruption about 1500 B.C. Below: Wrestling holds are detailed in a mural discovered in an eleventh-century Egyptian tomb at Beni Hasan.
Wolfgang Decker

picts her in the middle of the ceremony, accompanied by the bull-god Apis. The great exception was the pacific Amenophis IV (who ruled as Akheneten), best remembered for his heretical monotheistic religious views.

The Hyksos were expelled; the chariot remained. It was used for hunting as well as for waging war, and pharaohs were often portrayed wielding spears or drawing bows from the basket of a chariot. Chariot races as such were not part of ancient Egyptian culture, despite the suitability of the terrain. But later, during the Hellenistic age (fourth to first centuries B.C.), when Alexander the Great and his successors spread Greek culture throughout the eastern Mediterranean, chariot races became immensely popular in Alexandria and elsewhere in Egypt.

The Egyptians seem never to have been as passionate about horses as were the Hyksos, the Hittites (of what is now central Turkey), the Assyrians of Mesopotamia (modern Iraq), and other peoples of the Near East, who devoted enormous amounts of time and energy to their care and breeding. An obscure fourteenth-century Hittite named Kikkuli has left us a detailed account of these matters in writings sometimes referred to as *The Book of Horses.* The later Persian empire, which came close to overwhelming Greek civilization in 490 B.C., had similar roots. As Xenophon and other Greek historians made clear, equestrianism was an essential aspect of the education of a Persian prince, whose skill as a rider and hunter was a warranty of fitness to rule.

We know little about the role of sports in the great Minoan civilization, which reached its height on the island of Crete between 2200 and 1400 B.C. The written language remains mostly a mystery. But few frescoes have engendered more speculation than the one excavated at the Palace of Minos in Knossos, which shows adolescents, a boy and two girls, seizing the horns of a charging bull and somersaulting over its back. Ever since Arthur Evans discovered the image in 1900, scholars have wondered whether people really performed this dangerous stunt and, if so, what it signified. Was it a contest in which youths competed against each other, like modern gymnasts, or was the bull their adversary, as in a Spanish *corrida de toros?* Another fresco from Knossos, now at the National Museum in Athens, depicts a group of male and female spectators arranged on terraces, or tiers. Whether the audience consists of assembled worshipers or sports enthusiasts is not clear, but some scholars believe they are attending a bull-vaulting performance.

Vases, statuettes, coins, and other remains of Minoan culture attest to the popularity of hunting, boxing, and wrestling. Among the most tantalizing discoveries is a fresco from the island of Thera, a Minoan outpost, that shows two boys wearing some kind of boxing gloves, squaring off as if in a modern ring. The guides in Thera call them the "boxing princes," but whether they really were princes proving their fitness for rule or merely two boys at play remains the artist's secret.

The Etruscans, whose civilization flourished during the seventh century B.C. in the region north and west of Rome, were enthusiastic about sports, perhaps as a result of Greek influence. The murals inside the so-called Tomb of the Monkey and other burial sites feature Etruscan wrestling and boxing, while chariots race across the walls of the Tomb of the Olympics, Tomb of the Two-Horse Chariots, and others. The murals of the chariot races include the spectators and perhaps the officials, at least one of whom seems to have been female. Jean-Paul Thuillier, the leading authority on Etruscan sports, argues that these types of murals represented funeral games, traditionally held to honor the dead. This is plausible for many sports, but one wonders about the scenes in the Tomb of Hunting and Fishing, which include a fine picture of a man diving.

A mysterious Etruscan sport appears in the Tomb of the Augurs and Tomb of the Olympics. Known as the Phersu combat, from a word inscribed in the latter tomb, it pitted a masked man against a dog held on a leash by a second man. It may have inspired the later Roman combats of men and animals (*venationes*).

Scholars once believed that the Etruscans also gave the Romans the idea for their *munera,* combats between pairs of armed gladiators. An origin in Campania, south of Rome, or Samnia, east of Rome, now seems more likely. The precedent may have been a deadly funeral contest that had evolved from a still earlier ritual

of human sacrifice. Such sacrifices would have been made to provide dead heroes with an entourage and appease the gods of the underworld. Eventually, death in combat might have been deemed a better offering than the less thrilling sacrifice of a passive victim. The Romans took the ultimate step of making a fight to the death a gruesome form of entertainment. (The religious trappings of Rome's pagan games, incidentally, were what horrified Christian theologians like Tertullian, who deplored idolatry more than the martyrdom of his fellow believers.)

Funeral games may also have been the chief precursors of the Greek Olympics. Our best early source is not visual art or archeology but literature: Homer's *Iliad*, a ninth-century account of the Trojan War, which probably occurred in the thirteenth century B.C. In Book XXIII, the Greeks, who have not yet captured the city of Troy, celebrate funeral games for Patroklos, who has been slain by the Trojan hero Hektor. Lavish prizes are offered by the great Achilles, Patroklos's bosom friend.

The first event of the games is a chariot race, for which Achilles offers five prizes, chief of which is "a woman skilled in fair handiwork." Although Greece was not the ideal place to breed horses, chariot races were apparently common in Attica, Thessaly, and other places where the terrain was not too forbidding. The plain before "the topless towers of Ilium" provides a suitable course, but the race is a rough one, with the goddess Athene intervening to assure victory for her favorite, Diomedes. (Fair play, which requires that everyone compete under the same rules, is as much a nineteenth-century concept as the nearly defunct amateur rule of the modern Olympics.)

The chariot race is followed by the boxing and wrestling contests. The first is won

Young women and a young man (center figure) engage in the Minoan sport or ritual of vaulting over the back of a charging bull. The fresco was discovered in a labyrinthine palace on Crete that is regarded as one of the inspirations for the legend of Theseus and the Minotaur.
Robert Harding Picture Library

by Epeius, who fells his opponent with a mighty blow to the cheek. The second is declared a draw when neither Odysseus nor Ajax can throw the other. Then comes the footrace, in which Athene again intervenes, this time to favor Odysseus, whose limbs she lightens. The oafish Ajax she causes to slip and fall on offal left from the ritual slaughter of oxen.

When Ajax recovers, he is matched against Diomedes in potentially deadly armed combat, but the spectators stop the fight when Diomedes thrusts fiercely at Ajax's throat. Ajax has apparently suffered enough for a single day. The games conclude with the hurtling of the discus and with an archery contest in which the target is a dove tethered to a ship's mast. (The javelin contest, which was supposed to end the games, is canceled when Achilles, deciding that Agamemnon is certain to win anyway, gives him the prize.)

In Homer's dramatization, we can see that the games were a form of religious ritual, an appropriate way to worship the gods and to honor a fallen warrior. The contests also emphasized the skills and accomplishments of warriors. Both themes were eventually incorporated in the Greek Olympics, although the nature of the contestants changed somewhat. At first they were aristocratic warriors, but later, ordinary Greek men also competed and the role of the full-time athlete grew.

Pelops, a local hero said to be buried at Olympia, may have been honored by funeral games, and subsequent commemorative contests may explain why the site was chosen when the official games were instituted about 600 B.C. Originally, the Olympics probably consisted of a number of events, foremost of which was the short-distance race, or stade, from one end of the field to the other (a stadium for the

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Discovered in the tomb of Tutankhamon (ca. 1347–1338 B.C.), the back of a gold-plated throne, below, shows the young pharaoh hunting. Left: Tutankhamon wields a harpoon, perhaps in pursuit of a Nile hippopotamus.

footrace built later at Olympia may still be visited). The other events may have included a chariot race and the pentathlon or its constituents—a footrace, the discus, long jump, javelin, and wrestling. Other contests added over the years included longer footraces, a race in armor, and boys' events.

Neither the *Iliad*'s archery contest nor its armed combat were a part of the Olympic Games. Nor, despite the location of most Greek cities on the shores of the Aegean or on the banks of a river, were there swimming events at Olympia or any of the other sacred games. This was true even of the Isthmian Games, held at Corinth in honor of Poseidon, god of the sea.

Although the Greek athletic festivals were not the only, or even the earliest, ritualized sports of antiquity, they, more than any others, characterized an entire culture and embodied many of its people's highest aspirations. When, nearly a century ago, Pierre de Coubertin championed ancient Greece as an inspiration for modern games, he chose his model wisely. Amenophis II proved his divinity by his superhuman (and probably imaginary) athletic performance. Olympic victors, true exemplars of human physical excellence, won their immortality the hard way. □

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Sport of Kings

by Richard D. Mandell

On a magnificent carved relief from Karnak, Amenophis II, alone in a speeding two-horse chariot, shoots arrows at his target. The accompanying inscription tells us, "The perfect god, mighty in his strength...shoots at the copper ingots ...transfixing them like papyrus." The scene is more than 3,000 years old and, according to Wolfgang Decker in *Sports and Games of Ancient Egypt,* "deserves a leading place among the masterpieces illustrating the world history of sport." And so it does. But did this pictured act of balletic prettiness actually occur? In fact, it did not. And so we come upon a fundamental problem in this survey of Egyptian sports and indeed in almost any investigation of sports before modern times.

SPORTS AND GAMES OF ANCIENT EGYPT, by Wolfgang Decker, translated by Allen Guttmann. *Yale University Press, $40.00; 206 pp., illus.*

The Egyptians' obsessively lavish burials and the desert that preserved them have saved for our perusal enormous amounts of artifacts attesting to their life: ships, clothing, bakeries, politics, and entertainment. And among the last two classifications, we can include sports or some approximation of sports as we know it. We have balls for tossing, fighting sticks, board games, and even eight intact chariots. In Decker's book, the drawing of a chariot from an Eighteenth Dynasty tomb (1552–1306 B.C.) suggests a spare elegance rivaling that of our racing bicycle.

The translation and publication of this book is an event in the legitimization of sports as a solid historical subject. The German author, the reigning expert, tells us a lot. We learn of training runs for Nubian troops, of female gymnasts and hippopotamus hunts, and see reproduced inventories of allowable holds for wrestlers.

As in all surveys of Egypt, we are reminded yet again of the antiquity and stability of Egyptian society. Here, too, the interrupting incident of the Hyksos conquerors plays a big role. To regain control of their land, the Egyptians were forced to adopt the foreigners' war horses, chariots, and compound bows.

Although claiming to be a survey of forty centuries, this 200-page volume, shaped by available evidence, dwells on the wealth of pictorial and inscribed information from three generations of "athletic kings" who ruled just after the Hyksos: Tuthmosis III, Amenophis II, and Tuthmosis IV.

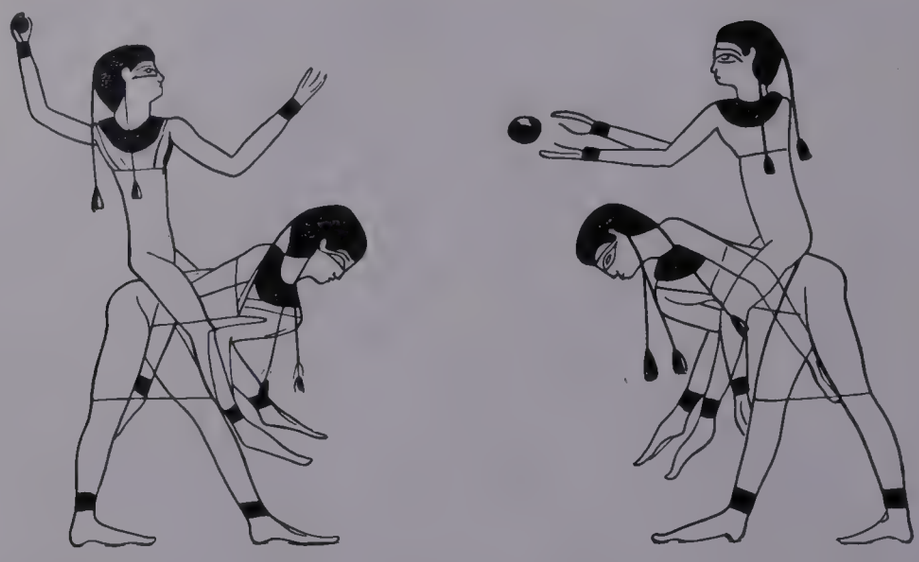
In this volume, more so than in other discussions of ancient public life, we learn that beneath the visual and written evidence, which communicates elegance and power, there was a miasma of fear. The ruling elites wanted protection from a recurrence of the Hyksos interruption and assurances against any sort of change. The lower orders feared disruptions in agricultural routine.

The descriptions of sports rituals, and especially the preserved reports of distance running and of marksmanship from chariots, celebrate impossible feats. The god-kings had to demonstrate awesome powers—less sport than propaganda—guaranteeing that they were supernaturally dependable. Decker admits that he describes "a society remote from our conception of reality." "Unlike Greece," he says, "where as early as the fifth century B.C. critical historians like Herodotus and Thucydides were analyzing events with more or less modern criteria, ancient Egypt had no 'private' historiography [of sports]...[royal inscriptions] report the course of events as they, ideally, *had* to have been."

Despite such demurs, we have here the overeagerness of an enthusiast. This

A ritual run was an important part of Egyptian jubilee festivals. A block from the Temple of Karnak shows Eighteenth Dynasty Queen Hatshepsut in full stride.
Wolfgang Decker

A "riding ball game," painted on a tomb wall at Beni Hasan, resembles a game played by the ancient Greeks.
Wolfgang Decker, from O. Keel, *Die Weisheit spielt vor Gott*



Egyptologist covering relatively new ground hopes to fix the high legitimacy of this subject, especially vis-á-vis the already well-established, indeed venerable, topic of athletic contests in classical Greece. (See Allen Guttmann's article, page 50, which explores the roots of sports in history.) Decker sometimes expresses a sort of gee-whiz attitude, as when he says that girls swam and muscular youths leaped in the air. Haven't children always played monkey-in-the-middle, leapfrog, and jump rope? Aren't gaffers perennially fishing and fowling? Throughout history, boys and men have raced across fields to or around a distant tree. I feel that we should be casual about all these things. Inventive play and contests have probably always been with us—anthropological constants.

There are some points that the author might have expanded upon. In a nice passage, he ranks the recently discovered "Running Stela of Taharqa" as being "among the most important known sources for ancient Egyptian sports." King Taharqa (690–664 B.C.) may have run part of a fifty-kilometer training run with his Nubian troops. Taharqa was a king in the Twenty-fifth—the so-called Ethiopian—Dynasty. Were black Africans noted for being outstanding distance runners this early? Is it possible that Decker has found some additional evidence for the now spicy discussions of the "blackness" of ancient cultures? Did Nubian athletic practices subsequently have some impact on the almost obsessive integration of sports in classical Greek life? In his partisanship for Egypt, these issues are not pursued.

Much of what is described here is of immense antiquity—much older than the sports of even preclassical, Homeric Greece. Decker gives the oldest evidence of funeral games (which subsequently played a large role in the *Iliad*). He suggests that the Egyptians invented the discus and contests in tossing it. Egypt had heroic archery contests long before the contest of Odysseus who, after his journeys, returned to bend his bow to compete with the suitors of Penelope. Yet the partisanship for his topic causes Decker merely to mention these incidents, which would enliven current debate in classical scholarship as to the independence and supremacy of high Greek culture. Egyptian sports, as well as other aspects of that culture, must have appealed to Greek travelers long before they had their own big sports festivals.

The book is nicely written and lucidly (indeed charmingly) translated. However, it has become an incident in a couple of scholarly polemics. A big debate among present-day sports scholars posits the uniqueness of modern sports, or, otherwise put, the extent to which publicly

viewed sports and the ceremonies around them are manifestations of, or even supports for, social and political life. Some writers on modern sports stress the uniqueness of the present: legalism or constitutionalism in the form of written rules; scientific precision as evidenced in training for high performance; and our cosmology as demonstrated by modern notions of time and space in the concept of the sports "record."

I am a player here. I claim that the

An Eighteenth Dynasty spoon, combining the forms of a duck and a swimming girl, was probably used to dispense ointments.
Musée du Louvre

orts record is a recent invention and a isman for the idea of progress in a disci- ined, industrialized, meritocratic mass ciety. Decker would make my distinc- ons fuzzy. He presents evidence for ecords" in Egypt. Successive Eighteenth ynasty kings, with much publicity, monstrated that they could control ghly bred horses and compound bows tter than their unbelievably (literally, for , in any case) excellent predecessors. ecker cites the numbered and measurable precision of the descriptions as "records," even though the incidents could not have realistically occurred. Roger Bannister, on the other hand, really did run a mile in 3 minutes 59.4 seconds at Iffley Road Track on May 6, 1954.

The survey is perhaps overly thorough. No evidence is neglected that bears tangentially on sports as we moderns know it. The author, who is a professor in Cologne, has employed all the earlier work in all the languages. Although he does not fix his subject as ranking with modern sports or that of ancient Greece (which was integrated into all aspects of high culture as never before or since), Decker's book is further proof that sports history is real history and that scholarly work can be good reading.

Richard D. Mandell, professor of history at the University of South Carolina, is author of The Olympics of 1972: A Munich Diary *and* Sport: A Cultural History.

Boykin Springs Longleaf, Texas

by Robert H. Mohlenbrock

When the first European settlers arrived in the southeastern United States, they found longleaf pine forests carpeting some 75,000 square miles of the Coastal Plain adjacent to the Atlantic Ocean and the Gulf of Mexico. During the last century, many of these longleaf pine stands were cut so that crops could be grown and cattle could graze; others were harvested for paper pulp and turpentine.

Clear-cut areas were frequently replanted with slash pine, a faster growing species suitable for paper pulp. Moreover, the suppression of natural forest fires was detrimental to the longleaf pines, which depend on fires to expose bare soil for good germination of their seeds and to suppress other woody plants. Southeastern Texas, for example, once contained 1,500 square miles of longleaf pine forests, largely in a wild, undisturbed region known as the Big Thicket. By 1935, barely thirty square miles of these old-growth stands remained, and today the state's Natural Heritage Program categorizes this dwindling habitat as threatened.

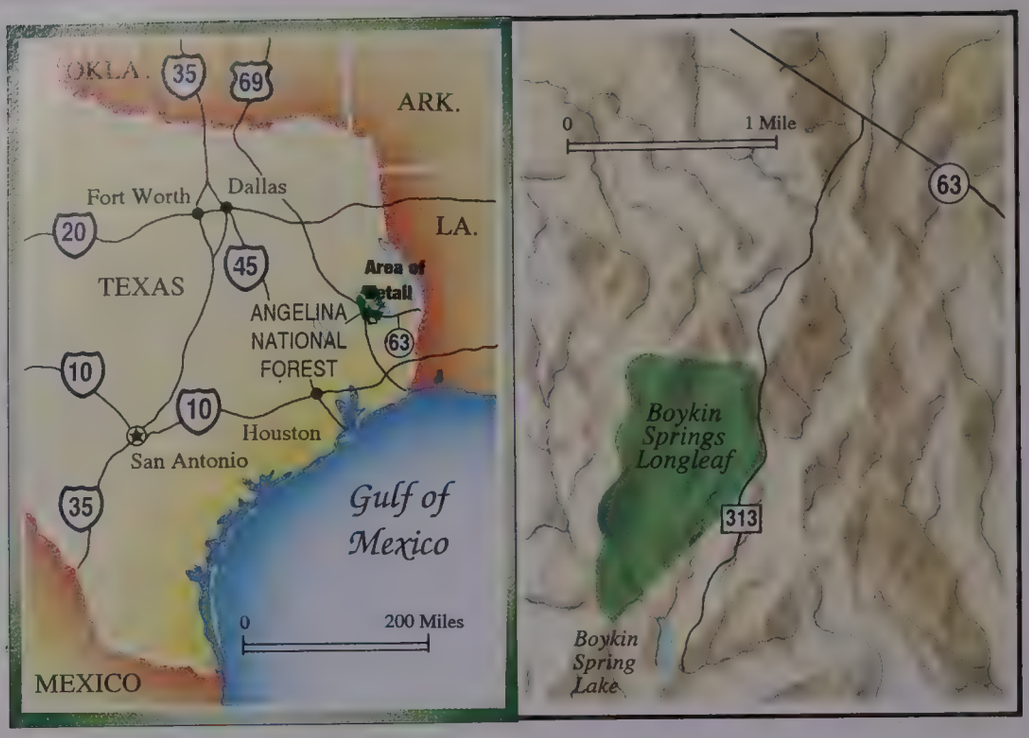
Pitcher plants and Texas sunnybells, left, bloom on a hillside seep bog, a moist contrast to the generally dry habitat at Boykin Springs Longleaf. Above: Young longleaf pines occupy a patch of hilly land.

Stephen Kirkpatrick

Throughout much of their range, from southeastern Virginia to southeastern Texas, longleaf pine stands are parklike, with an understory sparse in other woody species but rich in grasses and wildflowers. These communities, known as longleaf pine savannas, range from being very wet to very dry. A wet longleaf pine savanna, with saturated soil, was described in the November 1991 "This Land." An excellent example of a dry, upland one is Boykin Springs Longleaf, which occupies 350 acres of Texas's Angelina National Forest. Here water is scarce because it drains rapidly through the sandy soil of the region's rolling hills.

Research by botanists Edwin Bridges and Steve Orzell indicates that the oldest stands at Boykin Springs Longleaf date back more than a century. Human disturbance has been minimal, and burns by the Forest Service, carried out every three to five years during the nongrowing season, help maintain the balance of vegetation.

In most of the forest, the most common understory plants are bracken fern, poison oak, and a rich layer of grasses, including little bluestem, slender bluestem, and pineywoods dropseed. But Bridges and Orzell have identified nearly 250 species of flowering plants, from such shrubs as beautyberry, deerberry, St.-Andrew's-cross, highbush blueberry, and the aromatic wax myrtle to such wildflowers as blue larkspur, purple coneflower, dwarf yellow milkwort, blazing-star, rattlebox, and black-eyed Susan. Of particular inter-



Boykin Springs Longleaf

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est is the slender gay-feather, confined to only six adjacent counties in southeastern Texas. Known only since 1959, its lavender-purple spikes bloom in July.

In the driest parts of Boykin Springs Longleaf, where the soil is sandiest and has the fewest available nutrients, the longleaf pines become more scattered and a significant midcanopy appears, composed chiefly of bluejack oak. Vegetation on the forest floor is sparse: longleaf wild buckwheat and sawtooth nerveray are common, but sizable patches are bare or covered with lichens.

At the wetter extreme, seven hillside seepage bogs are found on short, steep, south-, southeast-, or southwest-facing slopes. These bogs have formed where a permeable layer of sandy soil lies atop a more impenetrable layer. Unable to continue its downward flow, percolating water spreads out horizontally, emerging from hillsides into shallow depressions. Most of the seepage bogs at Boykin Springs Longleaf are small, but Bridges and Orzell have recorded nearly 150 plant species in them, including nearly two dozen rare species.

Sphagnum moss frequently carpets the bog. Other typical species include two kinds of insect-trapping sundews, a pitcher plant, bogbuttons with spherical white flower heads atop slender leafless stems, nine kinds of yellow-eyed grasses (not true grasses), bog violet, rose pogonia orchid, bishop's weed, round-leaved and perfoliate-leaved bonesets. Cinnamon fern, royal fern, and Virginia chain fern grow three feet tall or more.

Bog coneflowers are confined to these and other hillside seep bogs in four southeastern Texas counties and one adjacent western Louisiana parish. Flowering vigorously in June, this three- to six-foot-tall plant bears up to a dozen flower heads; each has an elongated, purple-brown center, or cone, surrounded by several lemon yellow, petallike rays that hang downward. Large leaves as rough as sandpaper grow at the base of the plant, with progressively smaller leaves found partway up the stem. Despite the conspicuous nature of the bog coneflower, it was not described as a species until 1986.

Drummond's yellow-eyed grass has an unusual, disjunct range, growing in a few bogs from Tallahassee, Florida, to Gulfport, Mississippi, then in western Louisiana and southeastern Texas, including at Boykin Springs Longleaf. Another rare species is the yellow fringeless orchid, which until its rediscovery here, by Bridges and Orzell, was last seen in the state in 1950.

A few wetland trees and shrubs—such as sweet bay, red maple, swamp red bay, bayberry, and poison sumac—sometimes grow in the bogs. These species are most likely to intrude from an adjacent wetland forest if periodic fires are suppressed.

From a geographic and biological standpoint, the Coastal Plain of the Gulf of Mexico can be divided into the East and West Gulf Coastal Plain, with the Mississippi River being the dividing line. Biologists have tended to regard the longleaf pine savannas west of the Mississippi River as impoverished examples of those to the east. While this may be true of the shrubs and trees, the work by Bridges and Orzell has shown that when the herbaceous plants of the savannas are analyzed, the West Gulf Coastal Plain longleaf savannas boast nearly fifty species absent from the East.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.

Drummond's yellow-eyed grass, above, only a few inches tall, grows in scattered bogs on the Coastal Plain of the Gulf of Mexico. Right: Slender gay-feather, a member of the sunflower family, is confined to a few counties in southeastern Texas.
Photographs by Alfred Schotz

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Milk distribution at a market in Tamil Nadu, India

José Luis Pacanowski

Dog Days

by Gail S. Cleere

On July 1 the sun and the dog star Sirius are in conjunction; that is, lined up in a north–south direction in the sky. According to the ancients, this alignment will unleash the dog days—those long, hot, sultry days of summer. Sirius, the brightest star in the sky, is found in the constellation Canis Major, the Great Dog, just below and to the left of Orion throughout the winter months. As the earth orbits the sun, Sirius becomes lost to us in solar glare by the beginning of May. Then, after reaching conjunction with the sun in early July, Sirius begins to creep slowly back into view in the morning twilight, becoming visible by the latter part of August.

The idea that the hottest season of the year is ushered in by the reappearance of the brightest star in our sky is at least 5,000 years old. In ancient Egypt, Sirius reappeared several months earlier than it does today because of precession, that slow gyration of the earth's poles, which, with the passing centuries, causes the stars to appear to slip generally eastward with respect to the sky's reference circles.

Sirius is one of the few stars identified with absolute certainty in the ancient Egyptian records. The star's hieroglyph was a dog. The heliacal rising of Sirius (its first appearance in the morning sky just before sunrise) was a major event in ancient Egypt—signaling the rising of the Nile's floodwaters. The Egyptians believed that the Dog Star, called Sothis, brought the inundation of the river's delta, renewing the fertility of the fields. Several temples are oriented to the rising of Sirius. Just before the sealing of Egypt's royal tombs, grains, symbolic of life, were sprouted upon an image of the god Osiris—a possible source of the star's current name (although the name appears to be derived most directly from the Greek for "sparkling"). Even the ancient Egyptian calendar measured the year from one heliacal rising of Sirius to the next.

By the time of the ancient Greeks and Romans, however, Sirius had lost favor as the bringer of life and was thought to bring forth only fever and madness. Homer compared the glint on the armor of Achilles to the blaze of the Dog Star and further went on to tell us how unhealthy it was: "His burning breath taints the red air with fevers, plagues, and death." In the eighth century B.C., the Greek poet Hesiod wrote: "When Sirius parches head and knees, and the body is dried up by reason of heat, then sit in the shade and drink." Virgil instructed the farmer to sow his millet at the star's heliacal appearance and wrote in the *Aeneid:* "The Dog Star, that burning constellation, when he brings drought and diseases on sickly mortals, rises and saddens the sky with inauspicious light." Indeed, the Romans set about sacrificing young dogs to the star when it began to approach the sun's twilight glow in May, and it was they who coined the phrase *dies canisulariae,* or "dog days."

In medieval Europe, at about the time Sirius was appearing in the sky, the "spirit" of the first grain of summer was thought to take on the form of a dog, among other beasts. Dante spoke of "the great scourge of days canicular." And Shakespeare set the start of his tale of Romeo and Juliet at this time of the year. In this story of passion, temper, and "star-crossed" lovers, Benvolio says: "In these days is the mad blood stirring."

During the nineteenth century, a small, faint companion star was found orbiting Sirius. Called the Pup, Sirius B became one of the first white dwarf stars ever classified as such (1925). Now both sire and pup continue to dog us throughout the long, hot days of summer.

The Planets in July

Mercury reaches its greatest elongation east of the sun on the 5th and is therefore visible just after sunset early in the month. On the 1st, watch for the tiny sliver of the crescent moon passing just below the planet.

Venus rides very low in the western sky at sundown late in the month and is just barely visible in twilight. As the year progresses, Venus climbs slowly into the evening sky.

Mars rises between approximately 1:00 and 2:00 A.M., EDT, as July progresses. During the month, the red planet moves in an easterly direction among the stars of Aries and Taurus, and by month's end, it is in Taurus between the Pleiades and Hyades clusters. On the night of the 24th–25th, the waning crescent moon passes between Mars and the Pleiades.

Jupiter remains in Leo, setting with the Lion shortly after sundown. On the 4th, look for the giant gas planet nearly due west, above and to the right of the waxing crescent moon. Jupiter sets about two hours after the sun at midmonth, shining brightly at a respectable –1.8 magnitude.

Saturn rises about an hour after sunset at midmonth and by midnight is conveniently placed in the southeast in Capricornus. On the 16th, watch as the waning gibbous moon passes just above this lovely ringed planet.

Uranus and **Neptune** both reach opposition in July: the former on the 7th; the latter on the 9th, rising as the sun sets and setting as it rises. These planets remain within 2° of each other, just above and to the left of the "handle" of the Sagittarius teapot. On the 14th, viewers in eastern North America can watch as the full moon occults Neptune low in the southwestern sky just before sunrise.

Pluto continues its slow orbit around the sun (actually about 7,000 mph) near the border of the constellation Libra, high in the south at sunset. The planet remains closer to us than Neptune does and won't reclaim the distinction of the most distant planet until 1999.

The **Moon** reaches first quarter on the 6th at 10:43 P.M., EDT; full moon occurs on the 14th at 3:06 P.M., EDT; last-quarter moon falls on the 22d at 6:12 P.M., EDT; and new moon occurs on the 29th at 3:35 P.M., EDT.

Gail S. Cleere writes on popular astronomy and is a founding member of the International Dark Sky Association, an organization dedicated to preserving the skies for astronomy.

Some Arguments For Nuclear Energy Are Smaller Than Others.

Around the nuclear electric plant on Florida's Hutchinson Island, endangered wildlife have a safe haven. The baby sea turtles hatching on nearby beaches are more evidence of the truth about nuclear energy: it peacefully coexists with the environment.

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Artist Charles R. Knight (1874–1953) was a pioneer in the creation of accurate restorations of prehistoric animals. More than thirty of Knight's paintings and sculptures of early mammals will be on exhibit in the American Museum's Akeley Gallery from Friday, July 24, through the end of October. Featured are six large paintings, depicting scenes from various geological epochs, that were used as studies for Knight's murals in the Museum's fossil halls. Memorabilia related to Knight's life will also be on display.

GEOLOGY AND CLIMATE CHANGE

Recent studies of rock cores from New Jersey point to the powerful roles played by the motion of the planets and our moon in effecting global climate change. Paul Olsen, of the Lamont-Doherty Geological Observatory of Columbia University, will discuss these studies in an illustrated talk, "Using Local Geology as a Probe of Global Climate Change." The lecture, on Thursday, July 23, at 7:30 P.M. in the Sky Theater, is the second in a three-part series presented by the Hayden Planetarium in conjunction with the exhibition "Global Warming: Understanding the Forecast." Tickets are $8 ($6 for members). For information about ticket availability, upcoming lectures, and other Planetarium events, call (212) 769-5900.

FIELD TRIP: GLOBAL WARMING AND YOU

On Wednesday, July 15, and Wednesday, July 22, Sidney S. Horenstein, coordinator of the Museum's environmental public programs, will lead a workshop-field trip. This two-day program will examine domestic and industrial activities that release greenhouse gases, as well as explore the waste-cycle process, from a garbage collection center to a landfill area to a methane gas facility. For information and applications, call (212) 769-5310.

PLANET-WALK

The planet-walk is a 1,000-yard model of the solar system—with the earth the size of a peppercorn and the sun that of a bowling ball—devised in 1969 by astronomer-teacher Guy Ottewell. On Sunday, July 12,

The extinct ungulate Uintatherium *dominates the foreground of Charles R. Knight's painting of an Eocene environment.*

at 1:00 P.M., Robert Campanile will lead a free walking tour through this model universe. Participants will meet on the Museum's front steps, Central Park West and 79th Street. To register and for further information, call (212) 769-5566.

NATUREMAX

Through Saturday, October 31, Naturemax Theater will be showing *Ring of Fire* (daily at 10:30 and 11:30 A.M. and 1:30, 2:30, and 3:30 P.M.) and *Blue Planet* (daily at 12:30 and 4:30 P.M.). *Ring of Fire* explores the 30,000-mile circle of volcanoes of the Pacific rim, while *Blue Planet* presents film footage from four space shuttle flights. On Fridays and Saturdays, in addition to the weekday schedule, *Ring of Fire* and *We Are Born of Stars* will be featured at 6:00 and 7:30 P.M.

These events take place at the American Museum of Natural History, located on Central Park West at 79th Street in New York City. The Museum has a pay-what-you-wish admission policy. For more information call (212) 769-5100.

Estate of Lucy Knight Steel

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Kenya and Tanzania
February 11-26, 1993

Serengeti National Park, Ngorongoro Crater, Masai Mara Game Reserve, Samburu and Lake Manyara.

Archeology of Guatemala
February 20 - March 1, 1993

The ancient sites of Tikal and Iximche, as well as Guatemala City, Antigua, Chichicastenango and Lake Atitlan.

Folk Art and Archeology of the Oaxaca Valley
March 6-14, 1993

Towns, villages and markets in the Oaxaca Valley and the ancient sites of Monte Alban and Mitla.

Mexico's Copper Canyon and the Sierra Madres
March 13-20, 1993

The Sierra Madres, Copper Canyon and the towns of Creel, Divisadero and El Fuerte.

Archeology of the Yucatan, Chiapas and Tabasco
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The ancient sites of Chichen Itza, Uxmal, Coba, Tulum, Palenque and Mayapan.

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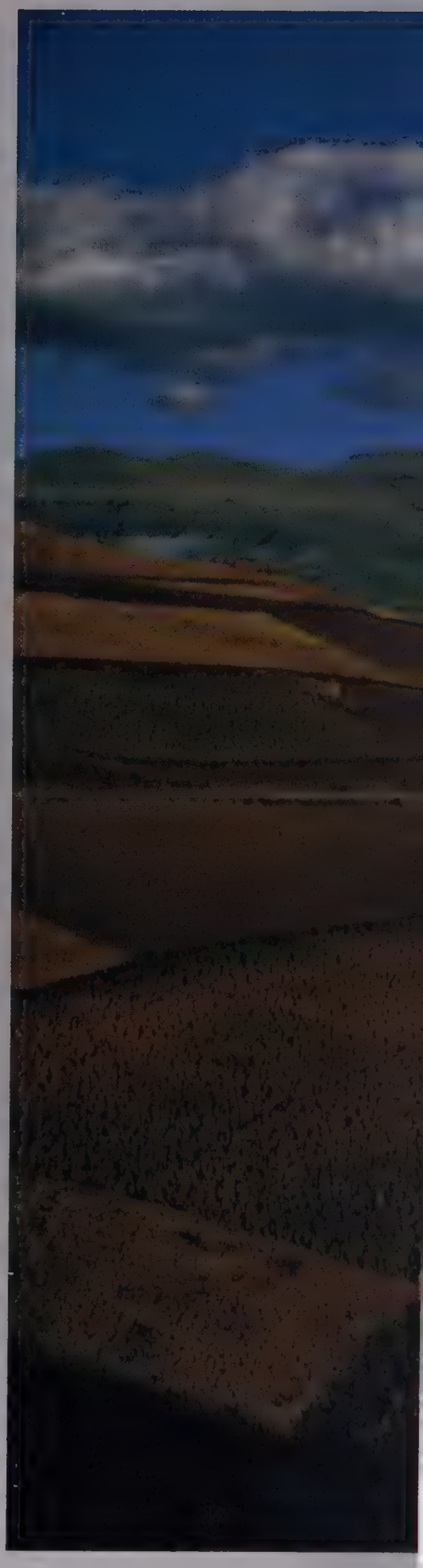
The Barley Eaters of Zumbagua

High in the mountains of Ecuador, an Old World grain is the staff of life

by Raymond Sokolov



New foods swim into our ken with amazing frequency these days. Are they fads or trends based on not much more than marketing or glamour? To some degree, yes, but in almost every case, the new foods that fashion seizes on have a down-to-earth, established role in other cultures, and they fit into some niche or fulfill some need in the evolving, polyglot cuisine of the United States.

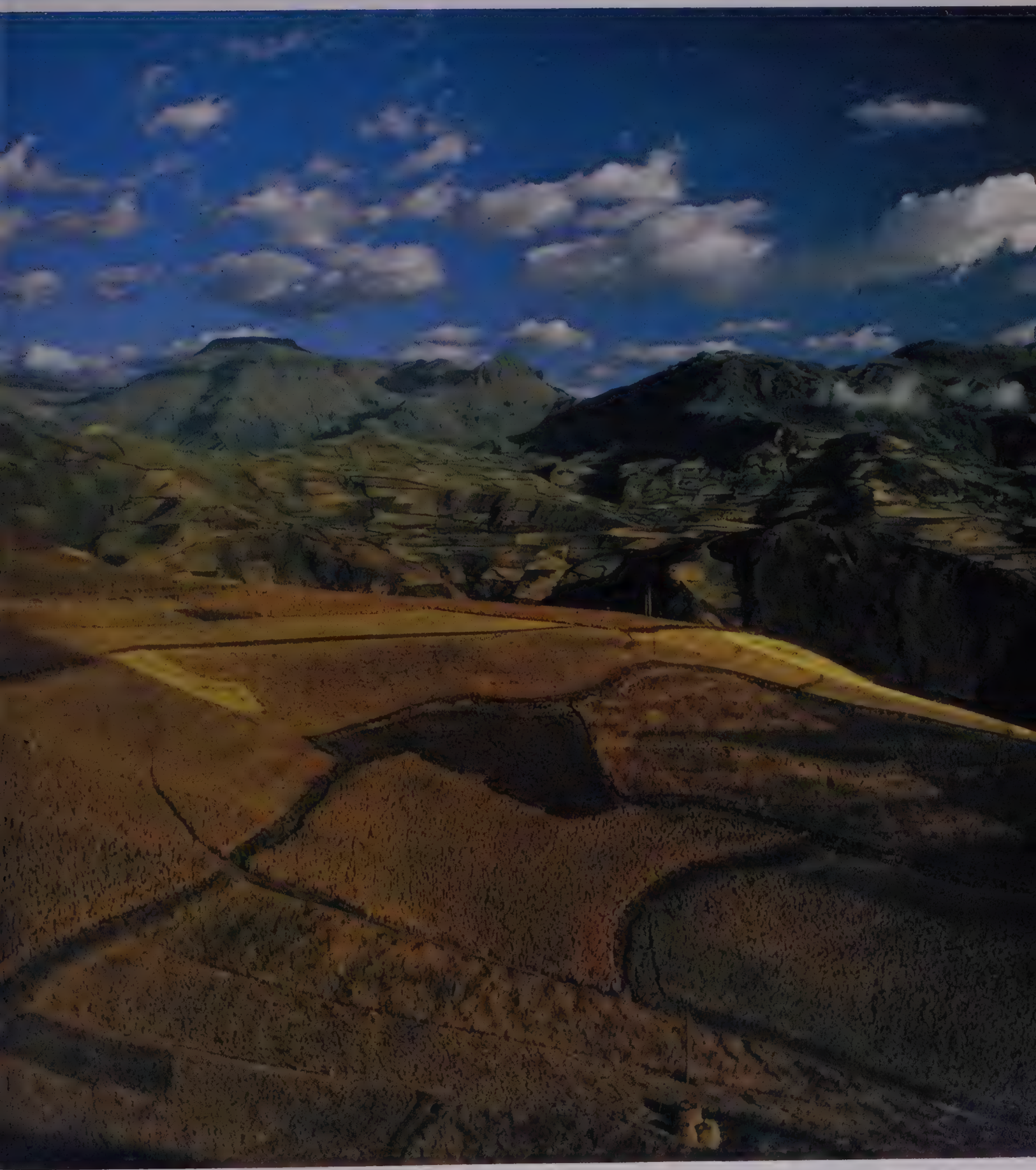
Often, new foods arrive with new immigrant groups. The sudden popularity of Sichuan food in the population at large was an indirect result of a change in the U.S. immigration law in the sixties that greatly expanded the chance for Chinese to settle here. But not every new immigrant wave brings with it something that Everyeater learns to love. Koreans, for example, have established themselves thoroughly in New York City. Their foods are profusely available in supermarkets and in scores of restaurants from midtown to thither Queens. But I know almost no non-Koreans who have acquired a taste for Korean specialities. Certainly it would be impossible to talk about any aspect of Korean food as a current fad or trend in this country, even though, ironically, Korean grocers are making a major contribution to everyone's gastronomic well-being with their excellent vegetable markets, which have spread from one end of town to the other.

But what about the exotic foods that do make it? Like best sellers, each one has its own special reasons for success. If it were possible to predict the next food trend, we would all have invested in pizza parlors. Even hindsight is sometimes not a totally reliable guide in such matters, since the perceptions people in one culture have about another can be grossly inaccurate, which means that the reasons Americans batten on some new food may bear very little relation to the actual role the food plays on its home ground. And recipes presented as authentic in Chicago or San Francisco may very well strike a native consumer as literally outlandish.

On top of all that, there is the factor of nutrition, a science whose shifting standards have pushed the consumer worried about diet and survival in diametrically opposite directions during the past forty years and longer. I can remember friends of my parents' "dieting" on steak and pushing potatoes aside. Today, of course, fatty red meat is a no-no in nutritionally correct circles and starchy pasta is as welcome as a wonder drug.

In this dust storm of misinformed or half-informed food frenzies, trend spotters might want to note the paradoxical rise of quinoa. Since it is almost invariably found in health food stores, we may assume that its main appeal is nutritional. Quinoa is said to supply the complete protein, all by itself. Secondarily, I think it is fair to say that its association with the poor, oppressed indigenous people of the high Andes gives it an attractive sociohistorical flavor. Here is a food untainted by any connection with animal fats or animal husbandry, rich in all the essential amino acids otherwise available only through meat or carefully arrived-at combinations of vegetables. And it comes to us from a blameless culture surviving for centuries in a harsh climate permitting only a Spar-

Barley fields in the Ecuadorian Andes: a legacy of the Spanish empire
Photographs by Loren McIntyre



Sopa de Quinoa

½ pound quinoa (washed)
1 pound pork, cubed
2 tablespoons cooking oil
2 tablespoons chopped onion
Salt
Ground cumin
Achiote
2 ounces ground roasted peanuts
2 cups milk
1 pound potatoes, peeled and diced
Chopped parsley

1. Combine quinoa with 2 quarts cold water in a large saucepan. Bring to a boil, then add the pork.
2. In a skillet, heat the oil and sauté the onion with salt, cumin, and a few grains of achiote until the onion is translucent.
3. Add the peanuts and the milk to the skillet, bring to a boil, reduce heat immediately to prevent overflowing, and simmer slowly for 5 minutes. Then stir the entire mixture into the "soup" from step 1.
4. Add the potatoes and cook until tender. Sprinkle with parsley and serve.

Yield: 3 to 4 servings

tan diet based chiefly on air-dried potatoes and quinoa. Quinoa, by this account, is good for you—and good.

As I made clear in last month's column, I think quinoa is a dandy grain, and I believe, along with its most fervent proponents, that it is good to eat, in every sense. But, as it turns out, neither the nutritional pitch made for it nor the ethnographic hagiography completely stands up to close scrutiny.

"Concern about the complete protein is passé," says Marion Nestle, chair of the Department of Nutrition at New York University. "The low amount of individual amino acids in vegetables is compensated for by quantity. There are two issues, calories and variety. Most people don't realize how easy it is to meet the recommended protein requirement."

As Nestle points out, all vegetables have all the dietary amino acids associated with animal protein, although not in the same amounts. But if people simply consume enough vegetables, they will still ingest enough of all the amino acids, as well as acquire enough calories for the body's basic energy requirements. Problems arise when people, especially children, depend on a single food for both calories and essential nutrients. For example, the classic deficiency disease pellagra afflicted people who ate almost nothing but corn.

These ideas are borne out by the fieldwork Mary J. Weismantel did for *Food, Gender, and Poverty in the Ecuadorian Andes* (University of Pennsylvania Press, 1988). She lived in the highland community of Zumbagua, studying this rural subsistence society through its food. What she recorded is in every way remarkable.

Here at last is a full-scale anthropological investigation of a culture built around food for its own value as a basic part of material culture and as an analytical lens.

Weismantel's specific findings are especially surprising. In the sensitive portrait she draws of a village not far, but spiritually remote, from Quito, we do not see a pristine Andean society surviving on potatoes and other native tubers with regular protein supplements from llamas and home-grown guinea pigs. In Zumbagua, poor Indians aren't eating potatoes much at all. They eat barley and fava beans, mostly barley:

> At the other extreme from the diet of the well-to-do, who occasionally eat entire meals that contain no barley and might perhaps go an entire day without eating it, is the monotonous diet of the extremely poor. In some households, day follows day without anything being cooked and eaten in the kitchen except barley gruel. In fortunate households, the potage may be flavored with sugar or salt or a lump of fat. A chopped onion or a few small potatoes might be added; in season, the leaves of adventives [weeds] can be stewed together with the grain. But I have frequently shared meals that consisted solely of ground barley and water.
>
> While most children in the parish do not appear to suffer from malnutrition, in these households there are periods of extremely inadequate diet. Nevertheless, this stone-ground barley meal is far superior to its equivalent among poor Ecuadorians who are severed from an agrarian base: babies in the cities eat white-flour gruel and drink sugar water. In Zumbagua, nutritionally inadequate meals (I have never seen a meal in which there was an insufficient *amount* of food; it is only the full nutritional complement that is sometimes missing) are typically a sporadic occurrence.

This barley cuisine is, to an overwhelming degree, the staff of life in a depressingly monochromatic diet, leaving only a minor place for traditional Andean crops. Weismantel says, "Barley is prepared in two different ways: heavily toasted, twice ground and sifted to a consistency as fine as corn starch (*máchia/masca*); or lightly toasted and coarsely ground (*arroz de cebada/arrus* [barley rice]). These two foods...form the foundation on which both diet and cuisine rest."

There is somewhat more variety o
poor Zumbaguan tables, but the full pi
ture given in Weismantel's study still pu
barley squarely in the center of mo
meals. Apparently, in the depleted soil
the region, barley is a more dependabl
crop. So in this Andean fastness, instea
of some pure survival of pre-Hispani
days, the visitor finds an almost total de
pendence on a grain long ago importe
from Europe to suit the habits of the Spar
ish colonists. Evidently, the Zumbaguan
manage to consume enough calories an
supplement their barley diet with jus
enough foods to survive.

Barley is also a staple in the world'
highest inhabited region, the Himalaya
but that is as much the Old World as Spai
To find barley as a staple anywhere in th
New World is a surprise, but especially i

the home of such world-beating starch sources as the potato and corn. The fava bean, another Old World import from Spain, is the other main calorie source. This irony compounds itself when Weismantel considers the place of the food of Zumbagua within the national cuisine of Ecuador.

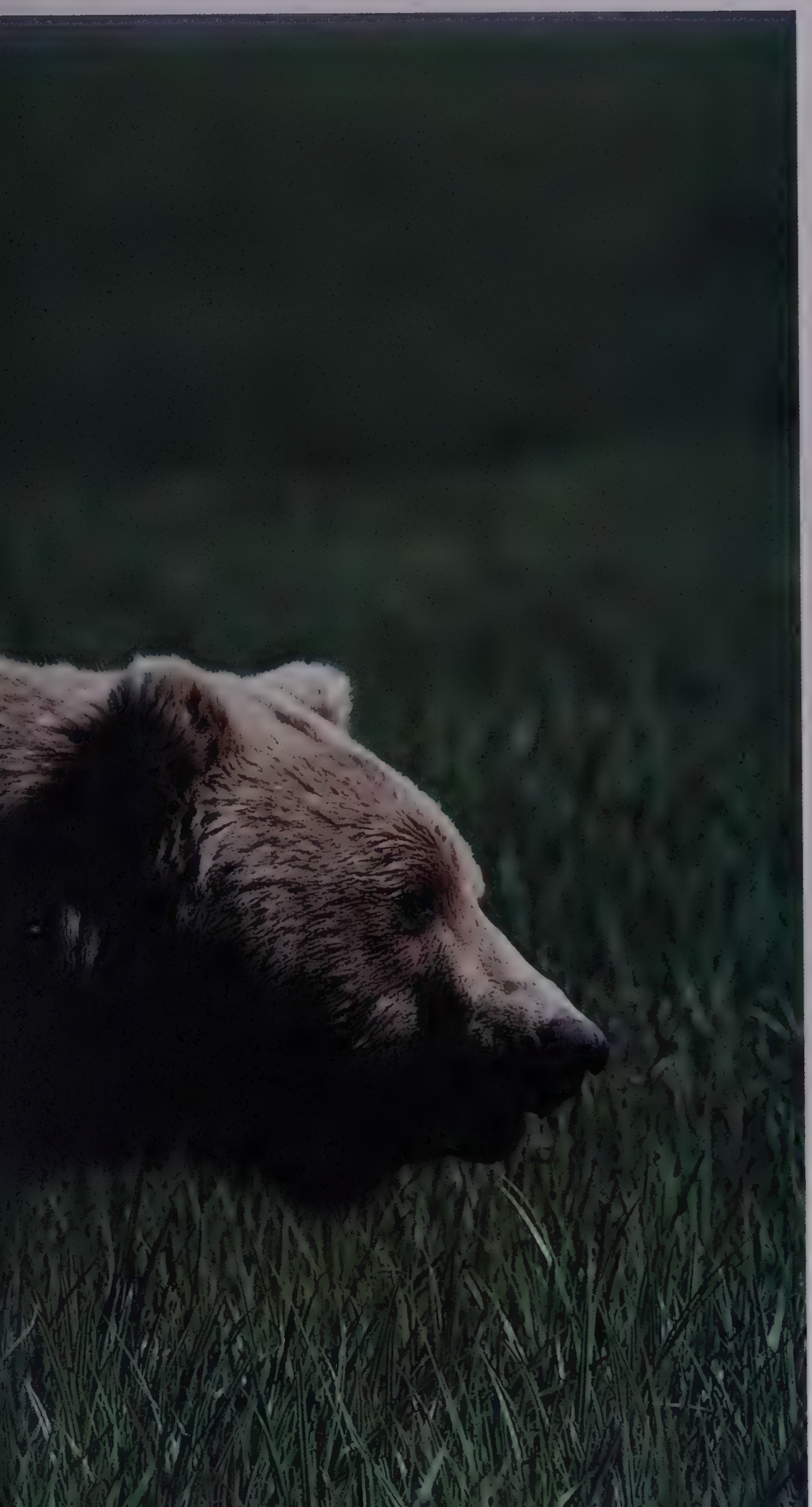
In most urban households in the country, the barley-centered foodways of Zumbagua are as foreign as they are to us. The cover of the popular Ecuadorian cookbook by Doña Juanita shows a plate of meat, vegetables, and potatoes with a mound of white rice topped by a fried egg. Rice dominates the dish. And it is rice that epitomizes the diet that poor Zumbaguans call "white." They know about this food because there are Zumbaguans who eat it. Many, perhaps most of them, are no whiter, in their skin color or ethnic heritage, than the barley eaters. As Weismantel explains it, whiteness in Zumbagua signifies an exotic way of life coming from outside the village and includes all sorts of differences. We might say that for Zumbaguans, to be white is to assimilate into the master culture of Quito and the coast. And rice epitomizes that world, which menaces Zumbaguan traditions as surely as the imported life style of American pop music and fast food strikes conservative residents of Quito as a threat to their civilization.

Rice is, of course, as much a legacy of the Spanish empire in Ecuador as is barley. And if one looks back far enough, rice in Spain is a legacy of the Moorish conquest of the Middle Ages, and the Moors got it from other Islamic peoples who themselves were in contact with Asia. But in the narrower perspective of a household clinging to life in Zumbagua, rice signifies the exotic, modern, cash-centered world of "whiteness."

For us, this remote social polarity is yet another proof of the complexity of life even in places we tend to think of as plain, simple, and static. I wonder what they would think in Zumbagua if someone told them that literally white North Americans are paying several times the local cost of rice to buy quinoa, because they think it will bring them long lives and pure souls. The idea is enough to make you yearn for a big bowl of barley gruel.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

Men reaping barley, the basic diet of Zumbagua's poor



Bear-back Rider

Given Alaska's size, why walk when you can ride? For several days in June, this grizzly bear cub was seen cruising the tidal flats of Kamishak Bay atop his mother. When other bears approached or when the cub emerged cold and wet from a river, he bounded up to his warm, secure perch and sometimes stayed aboard for an hour or so, leaving his sibling to follow along in the grass.

About four months old, the cubs had probably been out of their den for four to six weeks. Nursing, nibbling on tender grass shoots, and quarreling over fish scraps, they accompanied their mother as she grazed on protein-rich sedge grasses and caught early-run sockeye salmon. Because the abundant food of the estuaries attracts many other grizzlies, the sow was constantly guarding her young against other bears. Her clinging cub posed a problem when she stood to scan the tidal flats for threats or surged forward to defend her young. After a few days of tolerating her youngster's curious and, according to veteran grizzly watchers, exceptional behavior, the mother lost patience and shook the youngster off whenever he scrambled aboard.—*R. A.*

Photograph by
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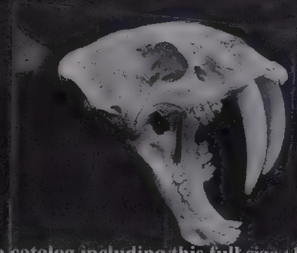
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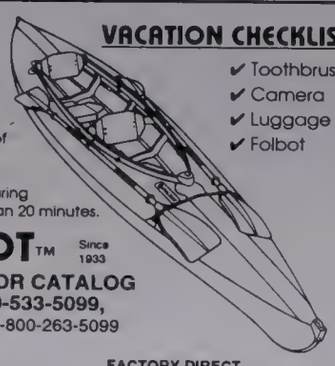
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Dafila Scott (page 26) became interested in Bewick's swans as a young teenager, when, recuperating from an illness, she observed the swans congregating on the pond near her home in Slimbridge, England. Her interest in these long-lived, paired-for-life birds continues today. Scott earned her doctorate from Cambridge University after a study of the social behavior of Bewick's swans, and she has served as a research fellow at Oxford and as a research scientist for the Wildfowl Trust in England. Recently, she has been able to complement her work on wintering swans by traveling to their summer breeding grounds on the Russian tundra. Scott plans to return to the Arctic to study competition for nesting sites between Bewick's and whooper swans, in a collaborative project with Russian scientists. In addition to her seasonal scientific studies, she works as a wildlife artist and in 1991 was elected to the Society of Wildlife Artists. For more information on Bewick's and other swans of the world, Scott recommends *The Swans,* by Peter Scott and the Wildfowl Trust (London: Michael Joseph, 1972). Essays on reproductive success in a variety of species can be found in *Reproductive Success,* edited by T. H. Clutton-Brock (Chicago: University of Chicago Press, 1988).

Well before *perestroika,* Moscow journalist-photographer **Alexander S. Milovsky** (page 34) yearned to explore and photograph the hundreds of regional cultures that made up the USSR. After leaving the national cultural publication *Kultura* where he had worked as a senior staff writer until 1980, Milovsky set out to document the vitality of sacred traditions in a supposedly atheistic society. His ten books, including a recent German-language guide to ancient towns of Russia (*Der Goldene Ring,* 1991), feature photographs of churches, tribal festivals, indigenous arts, monasteries, and little-seen rituals. About his article on a Siberian shaman, Milovsky commented, "These Nganasan people and their nature–spiri religion are practically unknown even to the Russian people. They live in a very remote region, and their religion had to go underground for years. I was like a guy from New York City penetrating the secret rites of an isolated pueblo somewhere in the American Southwest." Recommended books on the subject include *Shamanism: Soviet Studies of Traditional Religion in Siberia and Central Asia,* edited by Marjorie M. Balzer (Armonk: M. E. Sharpe, 1990), and *Shamanic Voices: A Survey of Visionary Narratives,* by Joan Halifax (New York: NAL-Dutton, 1979), which includes a first-person narrative by a Nganasan shaman.

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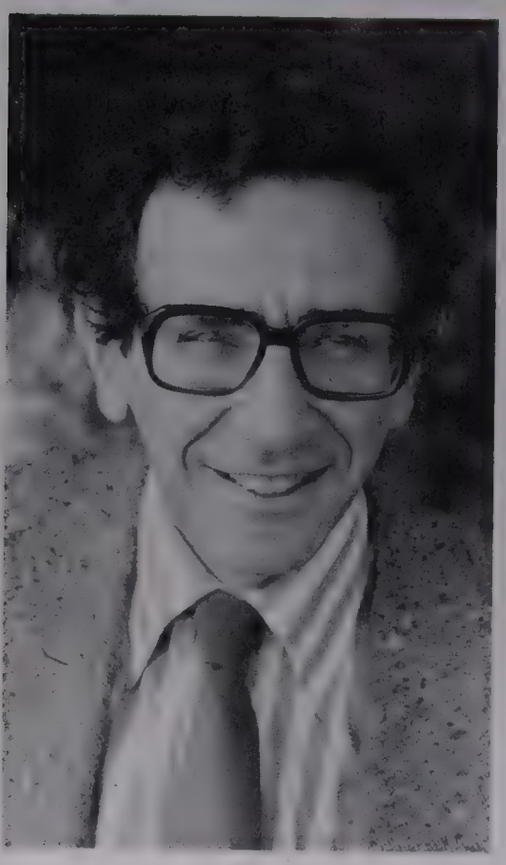
Sue Boinski (page 42) grew up in Wisconsin, playing in the woods and watching the deer, ducks, and squirrels that lived in them. Her life, she says, is still pretty much the same, except that the rich diversity of plants and animals in the tropical rain forests where she works makes her fieldwork several magnitudes more fun than her childhood roamings. The fun is tempered, however, by the realization that the rain forests are fast disappearing: forests she visited in Costa Rica only four years ago are gone. Boinski has recently completed field studies of the vocal behavior of squirrel monkeys, capuchin monkeys, and golden lion tamarins. While she expects to continue this work, she also hopes to coordinate another long-term ecological study of squirrel monkeys, this time with a population in northern South America. Boinski is now an assistant adjunct professor in the anthropology department of the University of Florida in Gainesville; the study reported on in the present article, however, was written while she was a staff fellow in the Laboratory of Comparative Ethology at the National Institutes of Health in Maryland. For additional reading, she recommends *Five New World Primates,* by John Terborgh (Princeton: Princeton University Press, 1984), and Frank H. Bronson's *Mammalian Reproductive Biology* (Chicago: University of Chicago Press, 1989).



While teaching in Germany in 1968, **Allen Guttmann** (page 50) attended a soccer game in Berlin's Olympic Stadium and marveled at the spectacle of 50,000 fans going wild over a sport that is practically ignored in the United States. This led him to wonder about the relationship of sports to culture, and the result has been a series of books devoted to sports history and sociology. His studies encompass the modern Olympic Games, spectators, women's sports, and the difference between ancient and modern sports. Guttmann recently completed an English translation of *Sports and Games of Ancient Egypt,* by Wolfgang Decker. A professor of English and American studies at Amherst College, he now plans to examine the diffusion of modern sports from England and America as a case of cultural imperialism. For additional reading he recommends *Athletics of the Ancient World,* by E. Norman Gardiner (Oxford: Oxford University Press, 1930).

In a photograph taken by her husban Tony, **Kathy Dawson** (page 76) rests the cliffs of Round Island, a sanctuary Alaska where walruses congregate on t beach. She photographed this month "Natural Moment" on one of her mar trips to remote locations in the Alaska bush. Having been an aerial mapping ph tographer, Dawson has logged mar hours in the air and continues to fly h Piper Super Cub from her home in A chorage to the isolated parts of the sta

that she loves best. Now a free-lance na ture photographer and writer, Dawson's work has appeared in many wildlife and news magazines. She is also the field editor for *Alaska* magazine. Currently, she is photographing in the Arctic National Wildlife Refuge and collaborating with her husband on a book about grizzlies, animals that have intrigued her since her first visit to Alaska's McNeil River State Wildlife Sanctuary in the 1970s. To capture the grizzlies on film, Dawson used a Nikon F3 and a 400mm telephoto lens.

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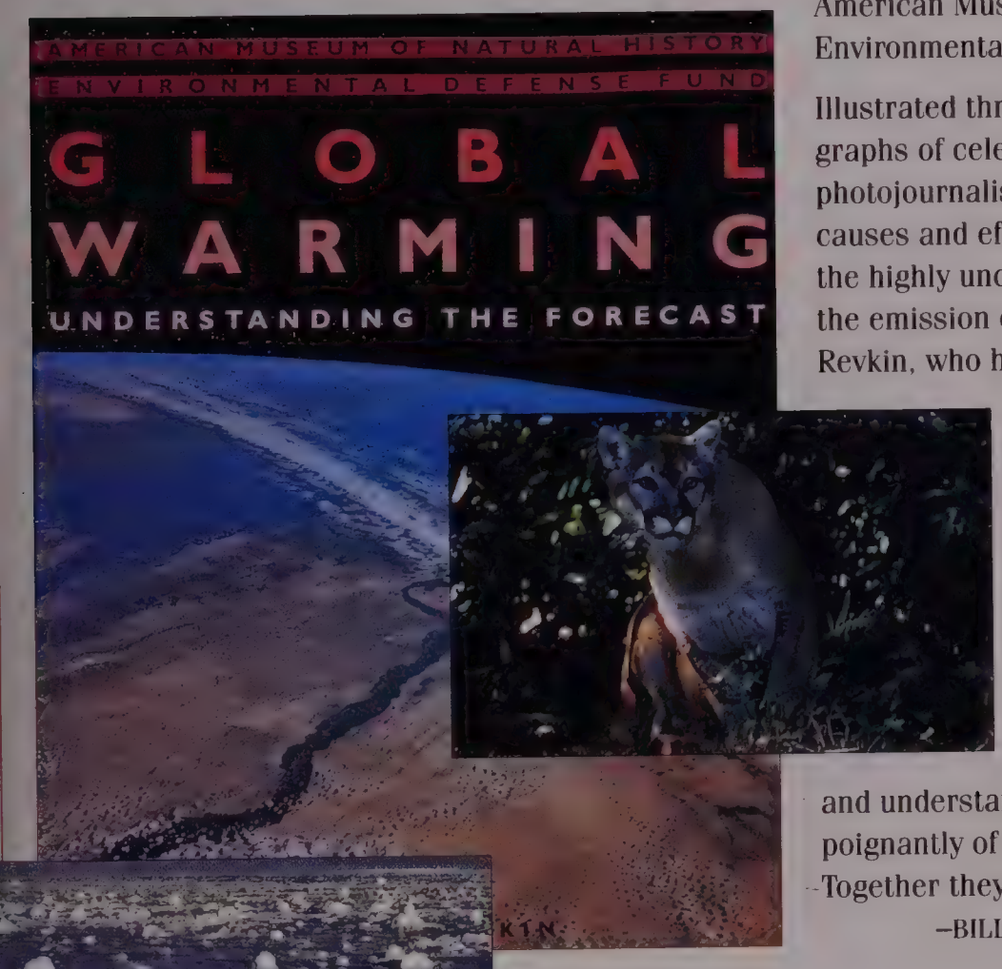

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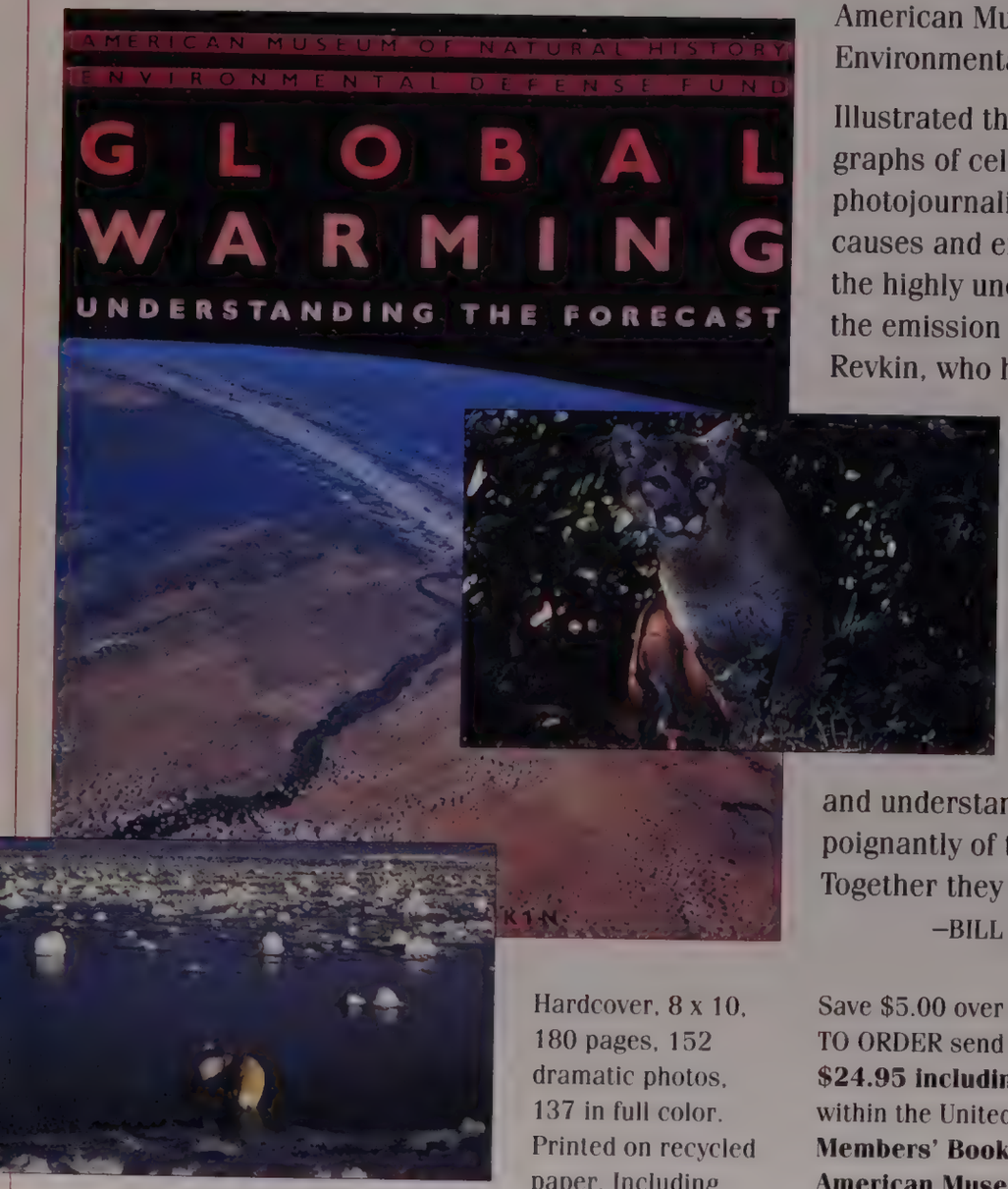

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COVER: *A Verreaux's sifaka feeds among the treetops in Madagascar. It is the closest living analogue of* Notharctus, *an extinct, lemurlike primate that lived in the forests of Wyoming some 50 million years ago. Story on page 54. Photograph by Frans Lanting; Minden Pictures.*

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NATURAL HISTORY (ISSN 0028-0712) is published monthly by the American Museum of Natural History, Central Park West at 79th Street, New York, N.Y. 10024. Subscriptions: $25.00 a year. In Canada and all other countries: $34.00 a year. Second-class postage paid at New York, N.Y., and at additional mailing offices.
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Must We Shoot Deer to Save Nature?

Alas, nature can't manage most nature reserves without our help

by Jared Diamond

Last October I spent a magically beautiful, but painfully upsetting, day in Fontenelle Forest near Omaha. On a floodplain in a loop of the Missouri River stood a climax forest of magnificent tall oaks, shagbark hickories, and lindens at the peak of their fall colors. In the last warm weather of autumn, the forest pools were teeming with America's loveliest water bird, the wood duck, while frogs basked on logs and deer browsed through the forest. From an overlook on a ridge rising out of the floodplain, the great river shone through the mist in the distance.

The silence, and the scene's peaceful magic, let me imagine that nothing had changed for thousands of years. I could easily forget that Fontenelle Forest is just a 1,300-acre reserve left from the Missouri's formerly extensive floodplain forests, most of which have long since been destroyed in the cause of human progress. Around the reserve stretch suburbs and farmlands, an artificial landscape against which Fontenelle Forest stands in contrast as if stamped out by a cookie cutter.

For the survival of the forest today, we can thank the Fontenelle Forest Association, a private nonprofit organization founded with the stated goal of preserving the forest in its natural state. Without any help from tax dollars, Omaha citizens raise money from private sources and serve without pay as directors. The association's rule 1 for visitors to the forest reads, "All plant and animal life is strictly protected"; rule 2, "No hunting, fishing, or weapons." The underlying philosophy for operating the reserve is one of no management, no interference by humans.

I wish I could report that these efforts were safeguarding the future of this wo derful ecosystem. They were not, and th was the painfully upsetting part of n visit. Closer examination of the fore showed that all the oaks, hickories, a lindens were mature trees; I saw n seedlings. On the forest floor were fe acorns and hickory nuts needed for th forest's continued regeneration. The sig felt like visiting an apparently thrivin country and suddenly realizing that it w inhabited mainly by old people, and th most of the infants and children had die While I expected to find dense thicke under the scattered crowns of the gre trees, the forest understory was actually s open that I could walk through most of i Most of the saplings were species lik ironwood and hackberry, which are pi neers in disturbed environments an which reproduce themselves by wind blown seeds or tiny fruits rather than b big nuts. Ecologists would describe th forest as in reverse succession: not th usual pattern of shrubs yielding with tim to saplings yielding in turn to tall old trees but the reverse. What's going wrong wit Fontenelle Forest?

A significant part of the answer in volves the deer I saw browsing in the for est. In the Omaha area, as throughou much of the Midwest and East, deer ar becoming abundant, thanks to our unin tended help. We provide the equivalent o supermarket conditions for deer by break ing the landscape into the habitat mosaic that they prefer, planting crops on whic they feed, and eliminating the big carni vores that used to keep down their num bers. The deer contribute to preventing Fontenelle Forest's regeneration by eating

corns and nuts, from which new oaks and ickories would sprout, and by browsing hrubs and low saplings. Deer thereby indirectly affect most of Fontenelle's other plant and animal species as well. Understory bird species that would normally breed or winter at Fontenelle are declining here, as are butterflies, which depend on understory plants for food, and wintering woodpeckers and jays, which feed on fallen nuts. The forest understory is changing a nursery for oak and hickory seedlings into a haven for "deer-proof" plants, such as poisonous snakeroot and stinging nettles.

This tragic situation arose out of the Fontenelle Forest Association's laudable policy of noninterference. Specifically, the association has rejected proposals to control deer numbers by shooting the animals. Anyone can understand why this proposal is anathema: it's diametrically opposed to rules 1 and 2 for reserve visitors, and to what one feels the guiding ethical principles of nature preservation should be. Imagine trying to explain to Sunday visitors why they shouldn't even pick flowers, while the reserve's directors are shooting away at the deer! Alas, rules 1 and 2 are thereby frustrating the association's declared ultimate goal of "preserving Fontenelle Forest in its natural state." The forest is instead becoming degraded.

Fontenelle exemplifies the paradox underlying a bitter policy dispute affecting all but perhaps the largest wilderness areas. This paradox is that the twin goals of noninterference with nature and of preserving pristine natural habitats are incompatible. Both wildlife managers and conservation biologists are being forced to

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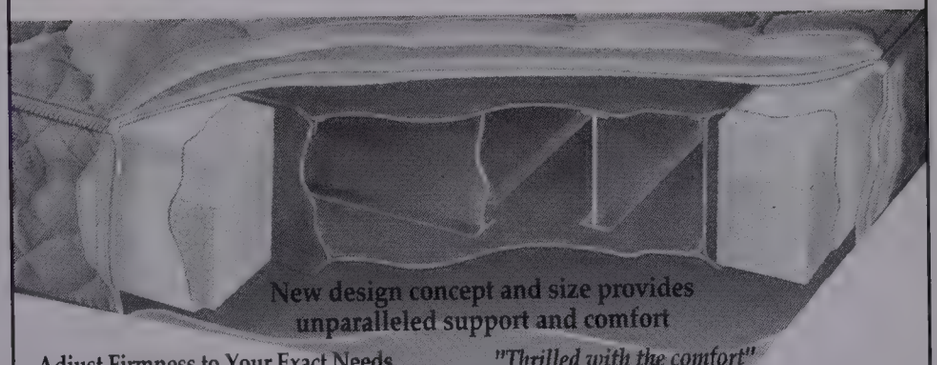

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acknowledge that nature reserves can't be left to nature alone to manage.

When I began to be active in conservation biology eighteen years ago, my assumption, like that of many of my colleagues, was that our guiding principle in managing nature reserves should be "hands off." For hundreds of millions of years before the rise of humans, nature managed just fine in preserving the world's biodiversity. Our own disastrous impacts are the very reason that we now have to be setting up nature reserves at all. Since even wildlife managers admit that they don't possess a fraction of the knowledge they need in order to manage ecosystems well, we felt that the first rule of nature reserve "management" should be to eliminate human interference.

This laissez-faire philosophy of reserve management may be reminding readers of Ronald Reagan's laissez-faire economic philosophy (get government off the backs of business, and business will do fine). This week, when the formerly healthy savings and loan association where I've banked for the last twenty years joined the hundreds of others that have collapsed, I became painfully aware of the disastrous consequences of laissez-faire economics. Laissez-faire doesn't work for nature reserves either. It has produced some spectacular and well-publicized disasters, such as the degradation of Kenya's Tsavo National Park, where park policy forbade shooting elephants even when they became so abundant that they began to destroy their own habitat. Similar disasters were averted at some other national parks only by "culling" (euphemistic for killing) elephants and other large mammals, a repugnant policy of last resort. Today, U.S. conservationists debate whether to shoot deer in Gettysburg National Military Park and bison and elk in Yellowstone National Park.

Why doesn't a laissez-faire policy work for nature reserves? Why can't they be left again to nature, as they always used to be?

The simplest answer to these questions can be given for reserves that have already lost a so-called keystone species—that is, a species of overwhelming importance to ecosystem function because it directly and indirectly affects habitat structure and the abundances of many other species. Into this category fall especially the top carnivores (such as lions and grizzly bears) and the big herbivores that they eat (such as zebras and elk). If these keystone species are gone, what we're trying to preserve is no longer the pristine self-sustaining ecosystem that nature could manage unassisted, but an already collapsing ecosystem incapable of sustaining itself. Big predators reduce prey numbers not only by killing but also by making it too dangerous for prey to forage in many places or at many times of day. (Do you think tha the elk you saw foraging in Yellowstone' open meadows in broad daylight woul have dared to do that if wolves had bee around?) Big herbivores in turn contro by their grazing and browsing and tram pling, the habitat on which mice, flowers and butterflies depend. Thus, surprising a it may at first seem, grizzly bears pro foundly affect butterfly abundance.

The classic example of mismanage ment of keystone species in the Unite States was the disastrous sequence o events on the Kaibab Plateau north of th Grand Canyon, where thousands of moun tain lions, wolves, coyotes, and bobcat were killed early in this century in an ef fort to protect 3,000 Rocky Mountai mule deer. The effort succeeded so wel that deer soared in numbers to nearly 100,000, severely overgrazed the vegeta tion, and destroyed populations of many other species before most of the dee themselves died of starvation.

A similar chain of events unfolded i South Africa's Hluhluwe-Umfolozi Re serve, where the practice of vermin con trol prevalent early in this century nearly exterminated all the top carnivores (lions spotted hyenas, cheetahs, and Africa hunting dogs). This led to the numbers o zebras, wildebeests, and nyala soaring ou of control, with such undesired results a overgrazing, soil erosion, and river silta-

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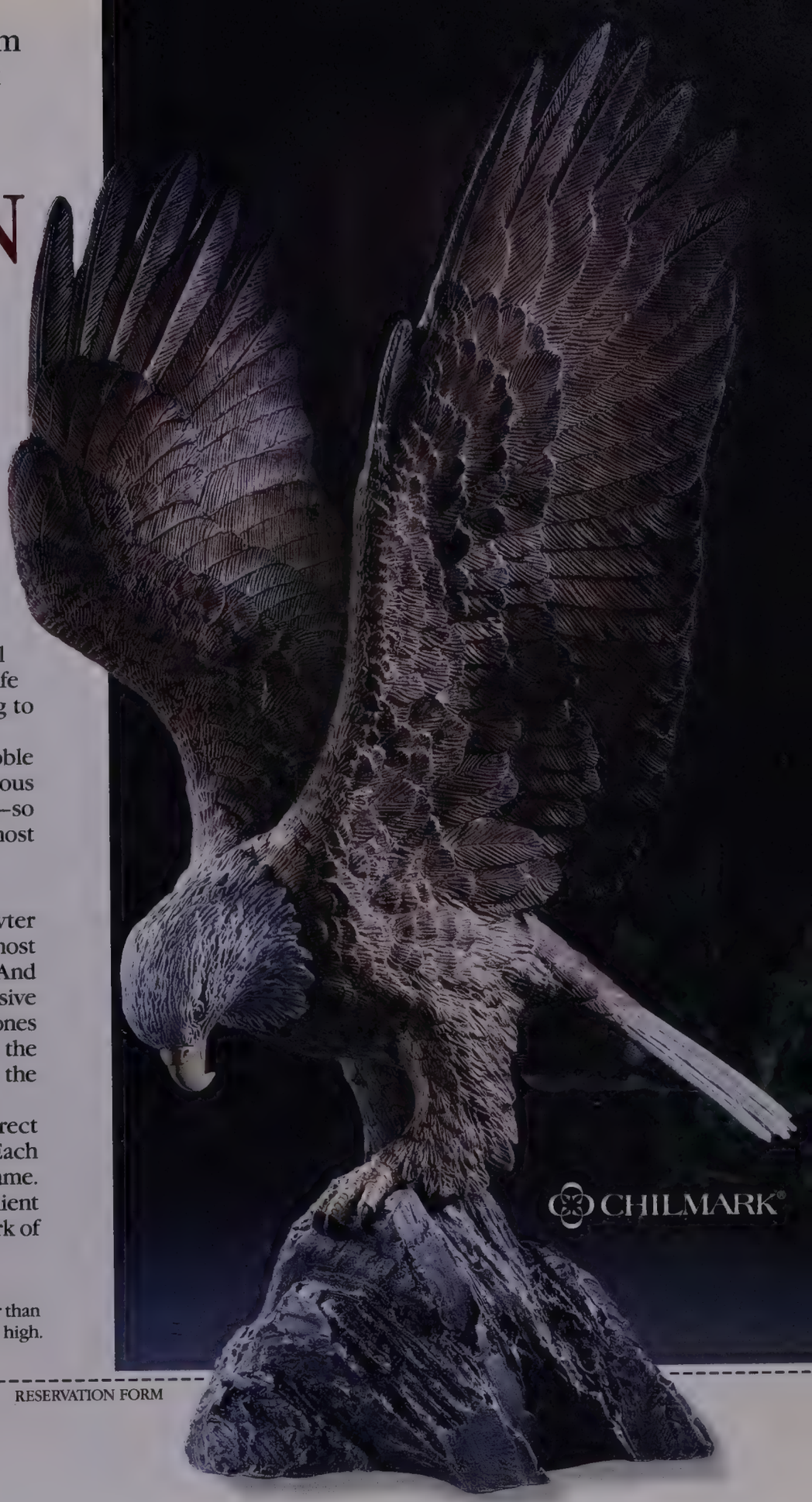
by
Jerry Klein



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tion; drastic declines in the rhinoceroses, waterbucks, bushbucks, and blue duikers because of habitat changes and competition; and local extinction of thirteen bird species dependent on the now-degraded grassland and river-edge habitats. The reserve managers were eventually forced to begin shooting zebras and wildebeests and to go to the expense of reintroducing the lions and cheetahs that they had worked so hard to eliminate. The Hluhluwe-Umfolozi story will sound painfully familiar to recent visitors to Yellowstone National Park, where our shooting-out of wolves and mountain lions caused elk numbers to soar to the high levels that we now see. Competition with all those elk helps explain why you probably won't see the bighorn sheep and deer that used to be more numerous in Yellowstone.

The disappearance of major predators provides one easily understood reason that the surviving rump communities within reserves may not be viable without our intervention. Now *we* have to control prey numbers, the former task of keystone carnivores. We also must deal with introduced pest species that can change habitats (and reserves) drastically. Notorious examples include the feral goats that have stripped bare much of the vegetation on the California Channel Islands, visible on a clear day from my home in Los Angeles; and the pigs and rats that are still at work exterminating the native plants and animals of Hawaii. Some people who would otherwise advocate hands-off management agree that it's proper to try to eliminate introduced pest species.

But such decisions are especially painful when the pest species is a native one that formerly lived in or near a reserve and whose numbers have skyrocketed because of human activities. For example, one of the greatest threats to the survival of Kirtland's warbler, confined as a breeder to jack pine habitats of Michigan, is nest parasitism by another native bird species, the brown-headed cowbird, which has profited by the spread of farms and pastureland. Moved by the plight of Kirtland's warbler, most bird watchers have accepted the painful necessity of an ongoing program that annually traps and asphyxiates thousands of cowbirds. The cowbirds have fewer defenders than do Fontenelle's deer, because they're less cute, and also because they threaten the survival of an entire species rather than of a local ecosystem.

Even reserves that retain their native species and haven't acquired pest species usually need ongoing human management because the area within the reserve is not ecologically self-contained. We stamp down our cookie cutter, convert everything outside the reserve boundaries to wheatfields, and—lo and behold—life within the reserve is supposed to go on unchanged. In reality, of course, life within the reserve was always sustained by processes originating outside the reserve, so that even the world's largest wilderness areas are not self-sustaining. The most obvious example of such processes is the arrival of waterborne and airborne nutrients from beyond the reserve's boundaries.

Less obvious but equally indispensable are arrivals of new animal "colonists." Small populations depend on immigrants to rescue them if they temporarily go extinct and to prevent inbreeding. A population of even as many as 100 animals is at risk. That's roughly the number of grizzly bears in Yellowstone, of African hunting dogs in Kruger National Park, and of lions in Hluhluwe-Umfolozi Reserve. But n reflect what 100 animals mean: roughly males and 50 females; perhaps 20 of ea may be of breeding age; many of those are siblings or cousins, so they're gene cally equivalent to perhaps 8 unrelated a imals; but only a couple of those anim succeed in producing most of the surv ing young. This quick calculation illu trates why populations of even 100 a mals are at great risk from inbreeding.

Because of inbreeding, the few rema ing elephants of South Africa's Addo N tional Park tend to be without tusks, t lions of Tanzania's Ngorongoro Cra may be losing their immune resistance diseases, and the wolves of Michiga Isle Royale National Park are becomi infertile. To combat the risk of inbreedi and promote exchange of genes, Sou Africa's conservation agencies now d vote a substantial fraction of their budg to airlifting rhinos and other large ma mals between reserves. Crazy as it m

Nils Peterso

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sound, I foresee the day when grizzly bears will have to be airlifted between Glacier National Park and Yellowstone.

Still another reason that cookie cutter reserves can't be self-sustaining is that some species used to migrate seasonally across what are now boundaries. Birds can continue to fly across a reserve's boundaries, but flightless mammals face problems. If the reserve is unfenced and the mammals wander outside into the surrounding farmland, they're likely to be shot. If the reserve is fenced, the mammals are forced to remain inside in all seasons, and if they're big herbivores, they may end up degrading the habitat. In what is now Kenya's Tsavo and Amboseli national parks, elephant populations used to migrate in and out seasonally. But when migration across the parks' boundaries became difficult, elephants overgrazed and destroyed the woodlands. Even South Africa's giant Kruger National Park began to be damaged by wildebeests when erection of a fence around the park severed migration routes. Human management of Kruger's wildebeests by shooting them now replaces nature's former management by migration.

Once again, Yellowstone raises these issues in acute form, as its soaring elk and bison populations spill out of the park in winter. The National Park Service can't just allow its elk and bison to breed without limit and then let those animals become someone else's problem when they invade adjacent ranches in the winter. With justice, ranchers hold strong views about those invasions, especially because brucellosis carried by bison can infect cattle. Pictures of your friendly park ranger, his trademark hat in one hand and a smoking gun in the other, standing beside the bison calf that he has just shot, don't fit our National Park Service's self-image. But the Park Service can't escape public anger by subcontracting the dirty work of shooting bison calves to other marksmen.

Unfortunately, we can't wriggle out of the odious task of managing nature reserves, even if all that we want to do is to maintain their status quo. The smaller the reserve, the more dependent it is on natural processes formerly originating outside its boundaries, and the more we'll have to intervene. Can our management efforts at least work toward the target of maintaining something like a "pristine condition," whatever that is?

The emerging answer to this question, too, has been painful to conservation biologists. For most of the earth's surface except Antarctica and some remote islands, the concept of a pristine condition is fictitious, because humans have had an impact on species and habitats for thousands of years. The pristine prehuman condition can't be restored; all we can do is to select one of many possible human-modified conditions as our target.

To appreciate this dilemma, again consider Yellowstone. Some have said that Yellowstone should be restored to its "natural" state as of 1872—the year that it was declared a national park—and then maintained in that state. But Europeans had by then already been modifying Yellowstone species and habitats for many years, by trapping beavers and other activities. Then should we instead restore Yellowstone to its state as of 1492, just before Europeans reached the New World? But Native Americans, like all other peoples, greatly affected their environments and had been modifying Yellowstone by hunting and by lighting fires for at least 10,000 years. Should we instead aim at restoring Yellowstone to its state as of 11,500 years ago, just before ancestral Indians arrived in the lower 48 states? That's an unattainable target, because the climate was different then, and because the disappearances of many big mammal species coincided with (were caused by?) that first arrival of Indians. We can never repopulate Yellowstone with its mammoths and saber-toothed cats because they're extinct. We could still repopulate it with its original lions and cheetahs, but you can imagine how ranchers who object to the proposed reintroduction of wolves into Yellowstone would feel about lions and cheetahs.

In short, for most of the earth there is no pristine state, unaffected by humans, to which we can point—at least, none that we could attain again. Instead, we must choose one among many human-altered states for our management efforts. We can't duck out of that responsibility by electing not to manage a reserve at all, because inaction is in effect a management choice, often carrying heavy consequences. Our choice involves difficult decisions about values, and we'll undoubtedly want to make different choices for different nature reserves.

For example, South Africa has elected to surround Kruger National Park and the Hluhluwe-Umfolozi Reserve with fences and to manage them for maximal diversity of life, even though Hluhluwe-Umfolozi is really too small to sustain a full suite of big carnivores. That decision will probably mean, among other things, having to bring in more lions periodically. The m
agers of another small, fenced So
African reserve, Rooiport, decided no
maintain large carnivores or other "d
gerous" big mammals, like elephants
buffaloes. That commits them to man
ing the many herbivore populations
shooting. But Rooiport thereby becam
reserve where it's safe for humans to w
around, whereas in Kruger you are stric
forbidden (for your own protection) to
out of your car. Rooiport doesn't ma
mize biodiversity, but it has its own ma
cal beauty. After a day of walking throu
Rooiport, my dreams that night were fil
with replays of the antelope pounding p
me in endless herds.

The corresponding policy decisions
Yellowstone are now being bitterly
bated. Some people feel that Yellowsto
should be managed for maximal biodiv
sity. In particular, they note that Yello
stone and Glacier are the only two parks
the lower 48 states large enough to susta
populations of our two top carnivor
wolves and grizzly bears. That choi
would mean reintroducing wolves to Y
lowstone and perhaps occasionally airli
ing in some grizzly bears to prevent i
breeding. But Yellowstone's grizzly bea
already pose public relations proble
and constitute real dangers to the safety
hikers. The National Park Service is relu
tant to compound this problem by brin
ing in wolves and thereby outragi
neighboring ranchers. But without wolv
and grizzly bears, the Park Service w
eventually have to outrage the public b
"culling" elk and bison. The Fontenel
Forest Association faces a simil
dilemma: it can shoot deer or it can let i
magnificent forest go on being degraded

It's easy for me, as a biologist witho
personal responsibility for these choice
to say that Yellowstone and Fontenel
should both be managed for biodiversit
I'm not the one who will have to explain
the public why they can't pick flowers in
reserve where deer are shot, or why the
should accept some dead sheep and hike
as a reasonable price to pay for the sati
faction of maximizing biodiversity.
comes down to what you, the public, wan
[Note: While reading the galley proofs
this piece, I learned that the Fontenell
Forest Association has decided to develo
a plan for active management of its forest.

*Jared Diamond teaches physiology a
UCLA Medical School and practices con
servation biology in Indonesian Ne
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Sweetness and Light

According to Aesop, the bee ranged through every corner of nature to furnish "mankind with the noblest of things"

by Stephen Jay Gould

"Sweet is pleasure after pain." This motto will be familiar to all, but I venture that few readers will know the source. The line is a paean to Bacchus, as voiced by soldiers to celebrate the joy that can follow a fight:

> Bacchus, ever fair and young,
> Drinking joys did first ordain.
> Bacchus' blessings are a treasure,
> Drinking is the soldier's pleasure...
> Sweet is pleasure after pain.

John Dryden's *Alexander's Feast,* source of these lines, tells the story of music's power over the emotions. (Dryden wrote the poem as an ode to Saint Cecilia, patron of music. Several composers set the verses for chorus and orchestra; Handel's version of 1736, written thirty-six years after Dryden's death and quoted above, remains a staple of the choral literature.) Alexander the Great, with a woman at his side and a glass from Bacchus in his hand, listens to Timotheus playing his lyre and succumbs to every emotion that the great musician evokes:

> Sooth'd with the sound, the king
> grew vain,
> Fought all his battles o'er again,
> And thrice he routed all his foes,
> And thrice he slew the slain.

The phenomenon of replaying old tunes is pervasive in our lives and cultures. And how could it be otherwise, for talented folks are many, but the good tunes few. Alfred North Whitehead commented that the entire European philosophical tradition "consists of a series of footnotes to Plato"—by which he did not accuse his colleagues (and, by implication, himself) of stupidity or plagiarism, but merely noted that truly great problems are evident and finite and therefore properly delineated (if not solved) by the first comprehensive thinker of extensive record. Alexander, at least, vaguely knew what he was doing—even if he was drunk, emotionally manipulated, and playing the oldest of all games in embellishing war stories (a hundred bucks says he could never have bested my late Uncle Milton in that genre).

Better stories, more ripe for satire in Dryden's mode, arise from *unconscious* rediscovery—especially when people, intoxicated with the excitement of a novel personal insight, think that they have just discovered an ancient truth for the very first time. A lovely example of this phenomenon has been circulating of late through the "letters to the editor" section of the leading British scientific journal, *Nature.*

On January 16, 1992, Zakaria Erzincli-oglu of the zoology department of Cambridge University wrote to complain most vociferously about a false and harmful use of language:

> One of the most absurd and persistent misuses of words in science is the use of the word "ancient" to describe species that flourished millions of years ago.... The truth is that organisms that lived long ago are "young" relative to those alive today.... The animals themselves are not ancient in any sense at all. They died out a long time ago when the Earth was young. Why do we persist in misusing the term in this way?

Ralph Estling then responded on February 20. (British periodicals do have a tendency to go on and on with disputes of such quirky interest but limited impo Some regard the tradition as cranky; I fi it charming.)

> From our point of view which is general the coordinate system we favor, trilobit and Aristotle are both; they were here ear (earlier than we were), younger than we ar but from our habitual standpoint of lookir back through time from where we happen be at the moment, they are ancient ar therefore older than we are.

Now I have no quarrel whatever wi Estling's pluralistic judgment, and I als agree with Erzinclioglu's closing poi that choice of words is neither trivial nc arbitrary:

> What does it matter whether we call earl life "ancient" or not? It can be said that it merely a convention and that it is shee pedantry to split hairs over this matter. I d not believe so. Words can play subtle trick in the mind and any scientific word tha might lead us astray in our thinking mu surely be replaced with one that is mor subtle.

I enter this fray to make a historica point, not a judgment. This dispute may b a goodie, but it is also a real oldie. Ou protagonists, in fact, have just rediscov ered one of our most ancient (o youngest?) linguistic wrangles, a classi paradox of our literary traditions. Franci Bacon made the canonical statement, i Latin epitome, in his *Advancement o Learning* (1605): *Antiquitas saeculi, ju ventus mundi* (or, roughly, "the good old days were the world's youth"). He late expanded this theme as aphorism 84 of his *Novum Organum.* (*The Organon* is a col-lective title of Aristotle's treatises on logic In claiming to start things again with a

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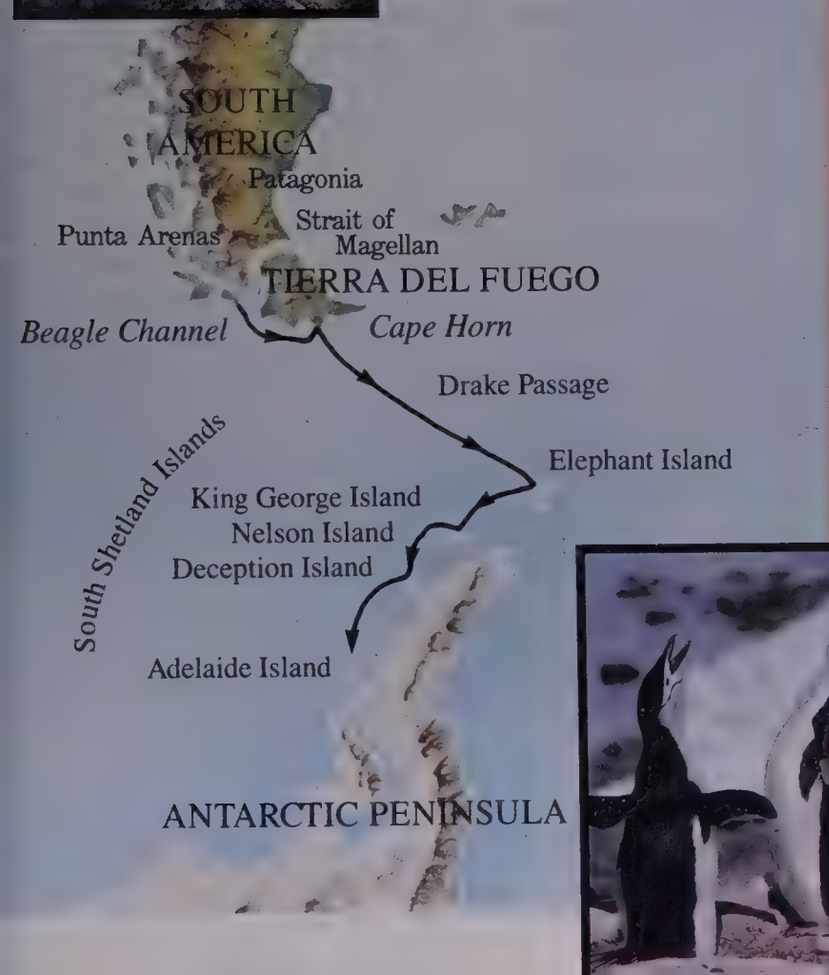

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New Organon, Bacon displayed his characteristic flair for self-promotion):

> The old age of the world…is the attribute of our own times, not of that earlier age in which the ancients lived; and which, though in respect of us it was the elder, yet in respect of the world it was the younger.

This puzzle became a major issue in British seventeenth-century thought and polemic for an interesting reason, centered on the origins of modern science, that I shall soon illustrate via Jonathan Swift. Scholars referred to this problem as the Baconian Paradox. Robert K. Merton, our leading sociologist of science, has traced the history and uses of this debate in his wonderful book *On the Shoulders of Giants* (first published in 1965 and continuously in print ever since). Merton grants Bacon the classical formulation but finds earlier hints and partial statements ranging from Giordano Bruno right back to the apocryphal book 2 Esdras of the Vulgate, or Latin Bible. Merton also documents a history of later rediscovery, with credit claimed for originality each time—a continuing tale with a new chapter now added from *Nature*. Jeremy Bentham, for example, left this aphorism among his unfinished papers (published posthumously in 1824): "What is the wisdom of the times called old? Is it the wisdom of gray hairs? No.—It is the wisdom of the cradle."

Unlike Alexander's slaying of the slain, I can offer no resolution of this issue to accompany my documentation of its venerability. The seventeenth-century debaters were right; Bacon's observation is a true paradox—that is, a seemingly self-contradictory or absurd statement that happens to be true. We get different answers from two equally proper and justifiable vantage points. Trilobites are both young (looking up from the origin of multicellular life) and old (looking back from 1992). Both perspectives, from both ends, are "correct"—and they do contradict. As with all the classical paradoxes that so fascinate and frustrate us, we both wince at and revel in Bacon's dictum because it embodies one of the inherent ambiguities of our complex lives. Just a week after Estling's response to Erzinclioglu, Rossini reached both his 200th and his 48th birthday on February 29, 1992 (yes, 48 and not 50; 1800 and 1900 were not leap years in our Gregorian calendar). Frederick, the pirate apprentice, subject to the same ambiguity (and faced with the prospect of bondage until his 21st birthday at age 88—not 84 because 1900 wasn't a leap year), gently touched the heart of this predicament in W. S. Gilbert's words: "How quaint the ways of paradox! / At common sense she gaily mocks!"

So why bother with this story at all? Is my correction and commentary any more than worthless pedantry and antiquarian "gotcha"? So might we judge this entire tale if Bacon's paradox did not illustrate such a central episode in the history of science and continue to prompt our attention to such an important issue today. Why did R. K. Merton bother to trace Bacon's paradox, and what are the "shoulders of giants" (in his title) anyway? Merton's book is a delightfully whimsical search through history—he gets all the way back to Bernard of Chartres in 1126—for the origin of a quotation usually attributed to Isaac Newton (from a letter he wrote to Robert Hooke): "If I have seen farther, it is by standing on the shoulders of giants." As Merton shows, Newton was staking no claim to linguistic novelty but merely repeating a phrase so widely regarded as common property that it demanded no quotation marks. Merton had two larger purposes beyond the sheer intellectual fun of romping through centuries in search of a phrase. First, he has spent a good slug of his career studying the phenomenon of "multiples" in scientific discovery. Our mythology venerates the lone genius, but most great innovations arise several times, often in virtual simultaneity (the calculus by Newton and Leibniz; natural selection by Darwin and Wallace). What better illustration for the social context of knowledge than a documentation of thoughts so pervasively "in the air" that several smart people pull them down at the same time? And what gentler illustration than a great quotation, supposedly the unique property of a singular genius but actually a common phrase for a millennium?

Second, Merton is an expert on that most fascinating period of the seventeenth century when the concept of progress, prompted by the beginnings of modern science, first became a dominant motif and driving force in Western culture. Dwarfs on the shoulders of giants may have been kicking around as a metaphor of modesty (or false modesty) for centuries, but Newton and his seventeenth-century colleagues elevated this image to new prestige and familiarity because it epitomized the ambivalence that any intellectual must feel in a world that sees itself as continually improving: namely, how can we pay homage to the past while still acknowledging our superiority? Dwarfs on the shoulders of giants is nearly ideal for such a purpose: we can praise our forebears as our intellectual superiors, while still maintaining that we now stand on higher ground.

Bacon's paradox, of course, just features another facet of the same imagery—and Merton treats this phrase as a subsidiary theme to dwarfs and giants. In some ways, Bacon's metaphor is even more biting, particularly if you wish to defend the rights of dwarfs (moderns) against the supposed wisdom of the giants (ancients). If those giants were just little

"The bad news is they're all dark meat."

kids in the world's youth, perhaps they weren't so transcendently brilliant—and perhaps we moderns, with our gray beards on the earth's old age, are the true repositories of accumulated wisdom.

As a scientist, I feel the tug and relevance of these twinned metaphors (dwarfs versus giants, and ancient times as the earth's youth) because their potent imagery is a product of the world that my profession helped to create. Debate on the comparative values of past and present did not dominate our discourse until historicism and the notion of progress became paramount in Western traditions—and these seminal ideas first arose with force during the seventeenth century, when the beginnings of modern science and commerce conjured up visions of steady and inexorable improvement. Why worry about whether the past was old or young if time runs in the repetitive cycles of Plato's Great Year and does not either advance or regress? Bacon's paradox only has meaning in the world constructed by science.

In the seventeenth century, all these swirling issues came to a sharp focus in a dispute that evoked great passion then and, in only slightly modified form, now engulfs the academy again—the "battle of the books," or the relative merit of ancient and modern learning and literature. (The seventeenth century pitted Aristotle against Descartes; now we counterpose the canon of "great books" by DWEMs—dead, white, European males—against a more diverse contemporary literature.) Consider the seventeenth-century context of the original battle: Latin and Greek formed the cornerstone of the curriculum; the learning of ancient Greece and Rome set an unsurpassable standard for all that would ever arise afterward (remember that the Renaissance received its name, meaning "rebirth," for attempting to recover, not to exceed, the glories of classical civilization).

Thus, the original battle of the books contrasted a curriculum of Greek and Roman classics with an attempt by modernists to grant equal (or greater) status to contemporary works of literature, philosophy, and science. Bacon himself supported the moderns and used his paradox to good effect, invoking the obvious simile of time's passage with the accumulation of knowledge in human aging:

> And truly as we look for greater knowledge of human things and a riper judgment in the old man than in the young…so in like manner from our age…much more might fairly be expected than from the ancient times, inasmuch as it is a more advanced age of the world.

For contrast, let us turn to the most famous defense ever penned by the other side—the brief for the ancients embodied in Jonathan Swift's wonderful and celebrated satire of 1704, *A Full and True Account of the Battle Fought Last Friday Between the Ancient and the Modern Books in St. James's Library,* usually called, for short, the *Battle of the Books.* All might have been well if the two parties had made a concordat and kept to their own proper spaces. But the librarian had fostered discord by intemperate mixtures in sheiving. As with nearly everything in Swift, the satirical reference is to something contemporary and specific, not universal and obvious. Swift comments here on an attempt by one of his colleagues to brand many of the fables attributed to Aesop as modern interpolations—hence meriting a reshelving of this ancient on the other side:

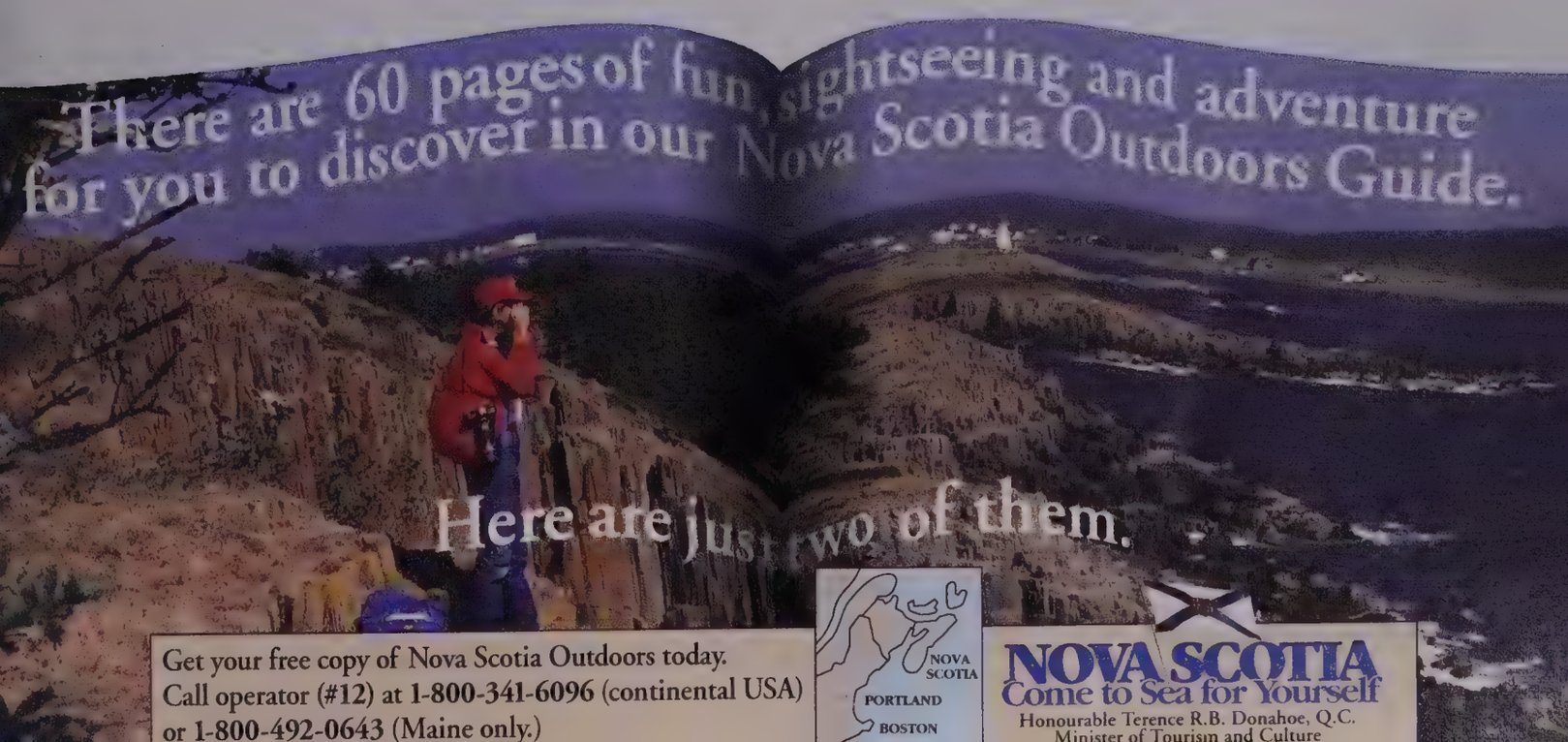
> In replacing his books, he was apt to mistake, and clap Descartes next to Aristotle; poor Plato had got [with] Hobbs…and Virgil was hemmed in with Dryden.

(Note how the source of my opening line, Swift's unloved colleague, becomes a primary symbol of modernism in this passage.)

Early in the text, both sides use Bacon's paradox to advance their respective arguments. (Swift, in a marginal note inserted at this point, explicitly places Bacon's argument in the context of disputes between early and recent learning by writing: "according to the Modern Paradox"):

> Discord grew extremely high, hot words passed on both sides, and ill blood was plentifully bred. Here a solitary ancient, squeezed up against a whole shelf of moderns, offered fairly to dispute the case, and to prove by manifest reasons, that the priority was due to them, from long possession.... But these [the moderns] denied the premises, and seemed very much to wonder, how the ancients could pretend to insist upon their antiquity, when it was so plain (if they went to that) that the moderns were much the more ancient of the two.

The bulk of Swift's text describes the actual battle, with his own sympathies for the ancients scarcely hid—as in this passage, where Aristotle misses the inventor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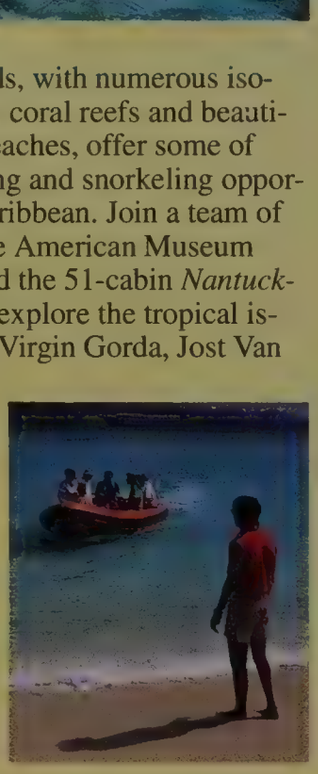

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of "the modern paradox" but kills Descartes instead (as the greatest French modern falls into the vortex of his own theory):

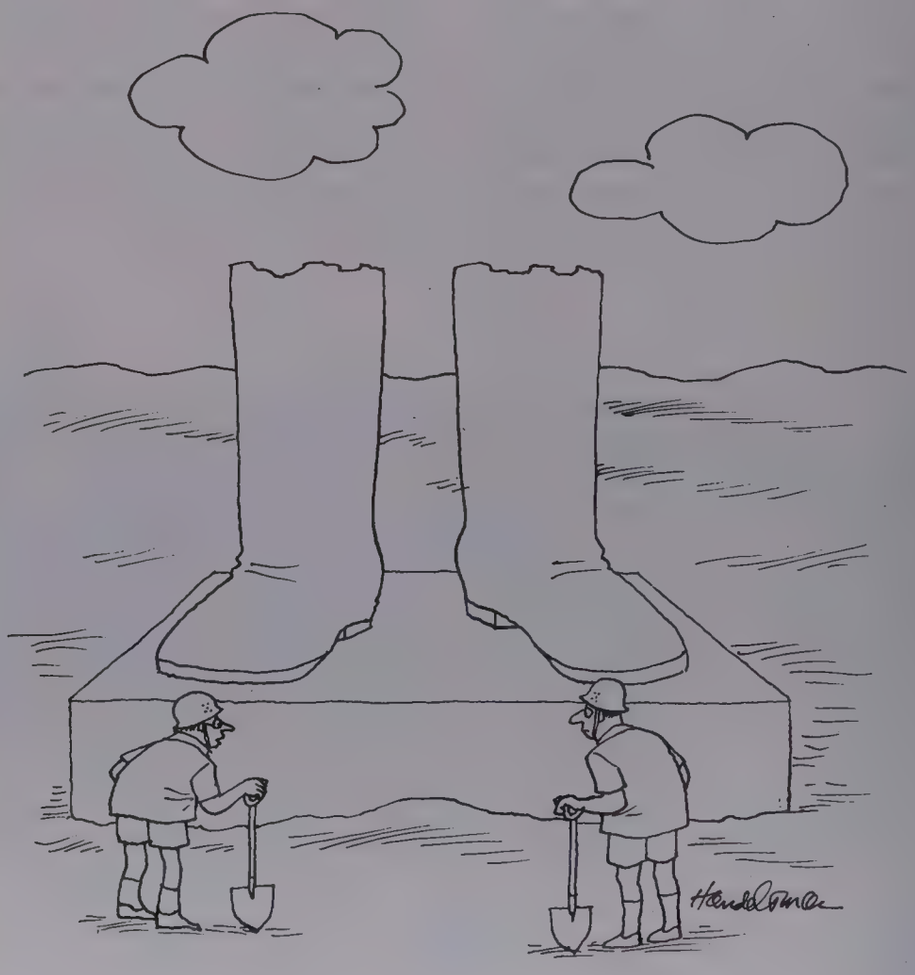
> Then Aristotle observing Bacon advance with a furious mien, drew his bow to the head, and let fly his arrow, which missed the valiant modern, and went hizzing over his head; but Descartes it hit: the steel point quickly found a defect in his head-piece; it pierced the leather and the pasteboard, and went in at his right eye. The torture of the pain, whirled the valiant bowman round, till death, like a star of superior influence, drew him into his own vortex.

But Swift introduces the actual battle with a verbal curtain raiser—a three-page gem that forms one of the greatest extended metaphors in all Western literature: the dispute of the spider (representing the moderns) and the bee (the ancients). In the library, a spider dwells "upon the highest corner of a large window." He is fat and satisfied, "swollen up to the first magnitude, by the destruction of infinite numbers of flies, whose spoils lay scattered before the gates of his palace, like human bones before the cave of some giant." (Swift, I assume, did not know that males of most orb-weaving spiders are small and do not build webs—and that his protagonist is undoubtedly a "she." So for that matter, come to think of it, is the industrious bee, also a "he" in this text.)

Swift leaves us in no doubt about the intended comparison; the spider, spinning such a mathematically sophisticated web from his own innards (and not relying on an external source of succor), is a scientific modern:

> The avenues to his castle were guarded with turnpikes, and palissadoes, all after the *modern* way of fortification [Swift's italics]. After you had passed several courts, you came to the center, wherein you might behold the constable himself in his own lodgings, which had windows fronting to each avenue, and ports to sally out upon all occasions of prey or defense. In this mansion, he had for some time dwelt in peace and plenty.

A bee then flies in through a broken pane and happens "to alight upon one of the outward walls of the spider's citadel." His weight breaks the spider's web, and the convulsions of the resultant tumult awaken the spider, causing him to run out in fear "that Beelzebub with all his legions, was come to revenge the death of many thousands of his subjects, whom the enemy had slain and devoured." (A nice



"There's no inscription. We'll probably never know whether it's Ozymandias or Lenin."

ouch. Beelzebub, a popular name for the devil, is literally "lord of the flies.") Instead, he finds only the bee and curses in a style called Swiftian ever since:

A plague split you...giddy son of a whore. .. Could you not look before you, and be damned? Do you think I have nothing else to do (in the Devil's name) but to mend and repair after your arse?

The spider, calming down, now takes up his intellectual role as a modern and excoriates the bee with the crucial argument from his side: you advocates of the ancients are just pitiful and unoriginal drones who can create nothing yourselves but can only forage among other people's antique insights (the flowers in the field, including nettles as well as objects of admitted beauty). We moderns build new intellectual structures from the heart of our own genius and discovery:

What art thou, but a vagabond without house or home, without stock or inheritance? Born to no possessions of your own, but a pair of wings, and a drone-pipe. Your livelihood is an universal plunder upon nature; a freebooter over fields and gardens; and for the sake of stealing, will rob the nettle as readily as a violet. Whereas I am a domestic animal, furnished with native stock within myself. This large castle (to show my improvements in the mathematics) is all built with my own hands, and the materials extracted altogether out of my own person.

The bee then responds for all devotees of ancient learning: I borrow but cause no harm in so doing, and I transmute what I borrow into new objects of great beauty and utility—honey and wax. But you, while claiming to build only from your own innards, must still destroy a hecatomb of flies for the raw material. Moreover, your vaunted web is weak, temporary, and ephemeral, whatever its supposed mathematical beauty (while the distillation of ancient knowledge endures forever). Finally, how can you claim virtue for a product of your own spinning if the material be poison based on your own gall and the effect thereof destruction?

I visit, indeed, all the flowers and blossoms of the field and the garden, but whatever I collect from thence, enriches myself, without the least injury to their beauty, their smell, or their taste. Now, for you, and your skill in architecture, and other mathematics, I have little to say: in that building of yours, there might, for aught I know, have been labor and method enough, but by woeful experience for us both, 'tis too plain, the materials are naught, and I hope you will henceforth take warning, and consider duration and matter, as well as method and art.

You boast, indeed, of being obliged to no other creature, but of drawing and spinning out all from yourself; that is to say, if we may judge of the liquor in the vessel by what issues out, you possess a good plentiful store of dirt and poison in your breast; and, tho' I would by no means, lessen or disparage your genuine stock of either, yet, I doubt, you are somewhat obliged for an increase of both, to a little foreign assistance.... In short, the question comes to this; whether is the nobler being of the two, that which by a lazy contemplation of four inches round; by an overweening pride, which feeding and engendering on itself, turns all into excrement and venom; produces nothing at last, but fly-bane and a cobweb; or that, which, by an universal range, with long search, much study, true judgment, and distinction of things, brings home honey and wax.

No one has ever said it better in nearly 300 years since. Most thoughtful people come down somewhere between the bee and the spider, but extremists on both sides are still using the same arguments. Current partisans of the spider claim that the "great books" of traditional learning (now including such former moderns as Swift and his *Gulliver's Travels*) have become both unreadable and irrelevant for modern students—and might as well be dropped (or lightly retained as a few excerpts for a lick and a promise) in favor of direct engagement with modern literature and science. At worst, they may actively disparage the old mainstays as nothing but repositories of prejudice written by that biased subset of humans called white males.

Current partisans of the bee can dispense worthy platitudes about upholding standards and retaining a canon universally validated by endurance through so much time and turmoil. But these good arguments are so often accompanied by blindness, or actual aversion, to the scientific and political complexities that permeate our daily lives and that all educated people must understand if they are to be effective and thoughtful in their professions. Moreover, defense of the great books is too often a smoke screen for political conservatism and maintenance of old privileges (particularly among folks like me—white professors past fifty who don't wish to concede that other kinds of people might have something important, beautiful, or enduring to say).

How can we resolve this ancient debate from the youth of time? In one sense we can't, at least to anyone's clear victory, for both sides have good arguments, just as in Bacon's paradox that once epitomized the ongoing argument. But an obvious solu-

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by

Gary Hush, student

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invoked a feature called Rear Curtain Sync, which, well, basically puts a blur behind a moving subject.

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tion stares us all in the face if only we could overcome the narrowness and parochiality that leads any partisan to fortify his barricade. The answer has been with us since Aristotle in the ancient days—in the form of the "golden mean." It speaks to us whenever the still, small voice of reason reconciles two warring parties by compelling attention to good points on both sides. It lies embodied in a famous epigram of Edmund Burke (1729–1797), once a modern in the original battle, but now an arch-conservative among the DWEMs: "All government—indeed, every human benefit and enjoyment, every virtue and every prudent act—is founded on compromise and barter." We must hybridize the bee and the spider, and then, in good Darwinian fashion, select for the best traits of both parents in a rigorous program of good breeding (education). The spider is surely right in extolling the technical beauty of his web, and the absolute need for all contemporary people to understand both the mechanics and aesthetics of its structure. But the bee cannot be faulted for insisting that fields of well-distilled wisdom await our entirely benign exploitation for enjoyment and enlightenment, and that we would be utter fools to bypass such a rich store.

I can argue the virtues of both sides, but since I live in the world of science and experience its parochialities on a more sustained and daily basis, I feel more impelled to advance the bee's cause. Distillation may be biased, but anything that endures for hundreds or thousands of years (at least in part by voluntary enjoyment rather than forced study) must contain something of value. No one celebrates diversity more than evolutionary biologists like myself; we love every one of those million beetle species, every variation of every scale count, every nuance in the coloration of feathers. But without some common mooring, we cannot talk to each other. And if we cannot talk, we cannot bargain, compromise, and understand. I am sad that I can no longer cite the most common lines from Shakespeare or the Bible in class and hold any hope of majority recognition. I am troubled that the primary lingua franca of shared culture may now be rock music of the last decade—not because I regard the genre as inherently unworthy but because I know that the language will soon change and therefore sow more barriers to intelligibility across generations. I am worried that people with inadequate knowledge of the history and literature of their culture will ultimately become entirely self-referential, like science fiction's most telling symbol: the happy fool who lives in the one-dimensional world of pointland and thinks he knows everything because he forms his entire universe. In this sense, the bee criticizes the spider properly—an ephemeral cobweb "four inches round" is a paltry sample of our big and beautiful world. I can't do much with a student who doesn't know multivariate statistics and the logic of natural selection; but I cannot make a good scientist—although I can forge an adequate technocrat—from a person who never reads beyond the professional journals of his own field.

I give the last words to Swift. When the bee and the spider finish their dispute, Aesop steps up and praises both parties, who have "admirably managed the dispute between them, have taken in the full strength of all that is to be said on both sides, and exhausted the substance of every argument pro and con." But he then, as befits his station and status, supports the bee. A person who ignores accumulated wisdom perishes in his own thin web:

> Erect your schemes with as much method and skill as you please; yet if the materials be nothing but dirt, spun out of your own entrails (the guts of modern brains) the edifice will conclude at last in a cobweb: the duration of which, like that of other spider webs, may be imputed to their being forgotten, or neglected, or hid in a corner.

Aesop ends by praising the bee and inventing a proverb that forms one of the loveliest conjunctions in English. I began this essay with a rough saying about sweetness; I end with the most noble trope on the same word. Did you know that the phrase "sweetness and light"—the abstractions of honey and wax—entered our lexicon of sayings as the culmination of Swift's defense, via Aesop, for the extended hive of our greatest intellectual traditions?

> As for us, the ancients; we are content with the bee, to pretend to nothing of our own, beyond our wings and our voice: that is to say, our flights and our language; for the rest, whatever we have got, has been by infinite labor, and search, and ranging through every corner of nature: the difference is, that instead of dirt and poison, we have rather chose to fill our hives with honey and wax, thus furnishing mankind with the two noblest of things, which are sweetness and light.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

Nikon ad cont'd.

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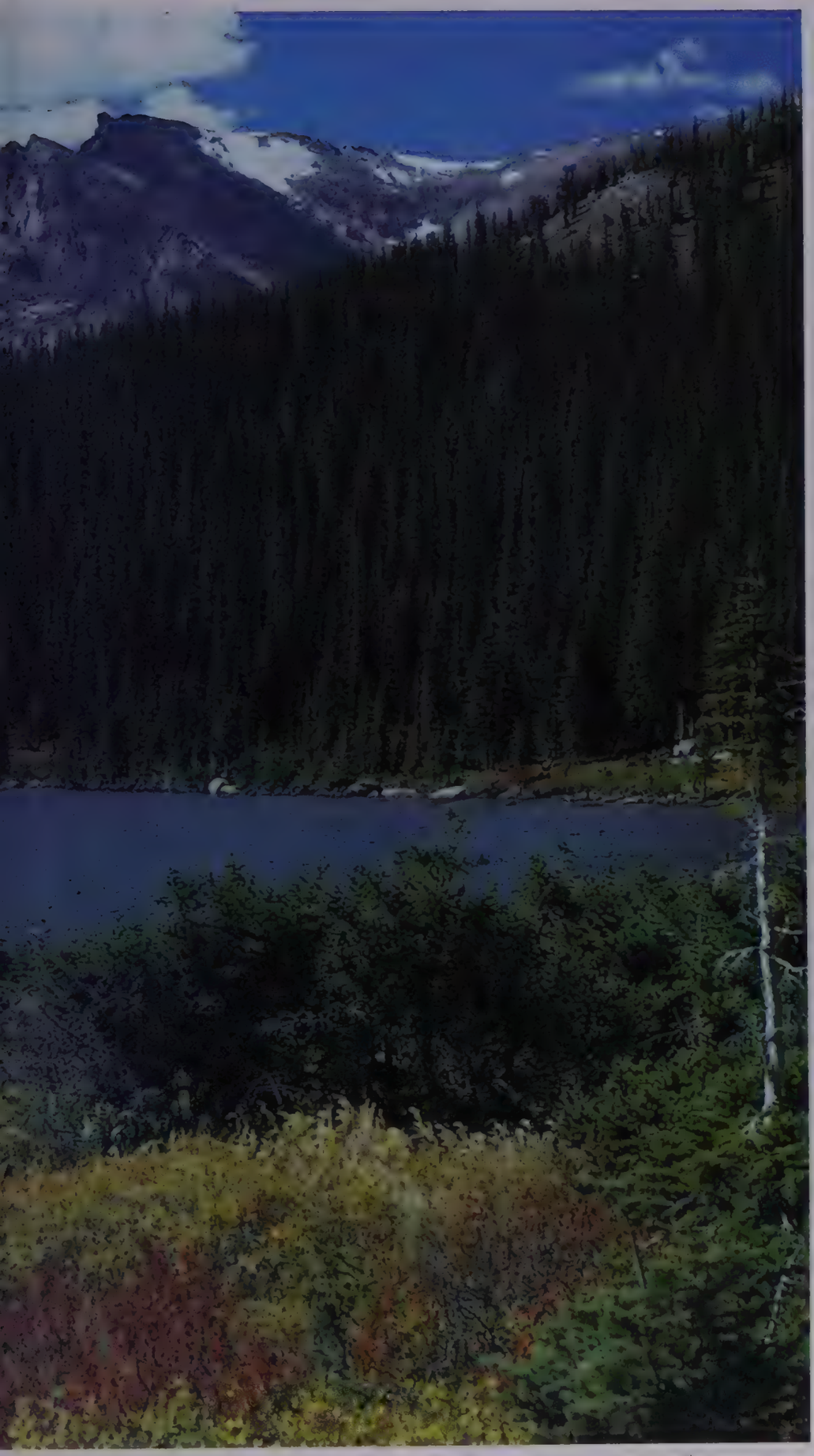
Kent and Donna Dannen

Long Lake Fens, Colorado

by Robert H. Mohlenbrock



Near the dwindling mining town of Ward, Colorado, a well-maintained Forest Service road climbs steadily westward toward the Continental Divide, the boundary between the Atlantic and Pacific watersheds. A backward glance to the east reveals the Great Plains, here only twenty miles from the Divide. After passing Brainard Lake, a popular recreation area and campground, the road ends at the Long Lake parking lot. Long Lake lies a little beyond, within the Indian Peaks Wilderness, a 43,000-acre region administered by the Arapaho and Roosevelt National Forests. The wilderness gets its name from several mountains more than 12,000 feet tall, including Arikaree, Navajo, Apache, Shoshoni, and Pawnee.

The trail to Long Lake begins in a small patch of subalpine forest. Engelmann spruce is the dominant tree at this elevation, 10,521 feet, while thickets of the wiry-stemmed, pale-green-leaved bilberry, a relative of the blueberry, occupy much of the understory. A myriad of shade-loving mountain wildflowers—including a blue Jacob's ladder, a white

East of the Continental Divide, Long Lake, left, is fed by abundant snowmelt. Above: Elephant's head grows in wet, open habitats.

R. and J. Pollock

Long Lake Fens

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lousewort, a yellow arnica, and twisted stalk (a cream-colored, lilylike flower)—brighten other parts of the forest floor.

The trail soon emerges into a huge opening containing Long Lake, with a backdrop of towering mountains more than 13,000 feet above sea level. The high peaks within view include Mount Navajo to the west on the Continental Divide and Mount Audubon to the northwest. As it approaches Long Lake, the trail divides. One branch continues west along the north side of the lake, the other leads south across a bridge over bubbling South Saint Vrain Creek. Hikers can walk around the lake either way or turn off to more remote destinations. One route leads across the Continental Divide at Pawnee Pass, while another goes to Isabelle Glacier, a nearby reminder of the Ice Age glaciers that sculpted the region.

Immediately east of the bridge, in a shallow depression carved out long ago by glaciers, lies a five-acre meadowlike area kept moist by the seepage of groundwater fed by the abundant snowmelt. This type of wet meadow is known as a fen because the water has become alkaline (a result of flowing through limestone rock). A narrow band of the shrubby flat-leaved willow, growing in foot-deep standing water, forms the fen's tangled border. Within, spongy, moundlike hummocks of assorted flowering plants overlie a gradually built-up foundation of sphagnum moss. Shallow rivulets of cold water separate the hummocks into tiny islets.

Near the fen's edge grow a tiny purple gentian, a magenta-flowered shooting star, and the remarkable elephant's head, whose purplish flower is an excellent replica of an elephant's head, complete with trunk. The fen's interior contains an astounding collection of grasses, sedges, and rushes, many of them rare, all of them adapted to a cold, wet habitat and short growing season of no more than three and a half months. The most common grass is the tufted, bluish-tinted hair grass. An occasional white, fluffy head of narrow-leaved cotton grass (actually a sedge) stands a foot above the other vegetation. Various sedges belonging to the genus *Carex,* none more than six inches tall, make up most of the rest of the vegetation.

The *Carex* sedges are perennials whose underground rhizomes store an abundance of carbohydrates to fuel the plants during the short growing season. The rhizomes also stabilize the plants in their soggy habitat. In six black-headed species, dark scales surround the plants' tiny, petalless flowers, giving the flower clusters a black appearance and absorbing heat. In this fen even the flower heads of the somewhat taller Nebraska sedge appear black, although at lower elevations they are more typically brown.

A second fen lies west of the trail, in a narrow strip along the south edge of Long Lake. A fringe of subalpine forest along its southern border provides shade for a number of species that do not survive out in the open. Among them are another black-headed *Carex* sedge, white marsh marigold, and Parry's pink primrose. Also distinguishing this fen are isolated patches of fine, yellowish gravel covered by about one inch of clear water. Although most plants find this wet, rocky ground inhospitable, two diminutive rushes grow here, each barely four inches high.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.

A black-headed sedge of the genus Carex, *above, mingles inconspicuously with rose crown. Right: Early spring growth provides the first hints of green to the open fen east of Long Lake.*
Kent and Donna Dannen

Steven C. Wilson; Enthe

Nature Unforced

"Picking wild berries is the sweetest and best of our vagrant summer pleasures"

by Ronald Jager

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willing to give,
Not forcing her hand with
harrow and plow.

—Robert Frost
"Blueberries"

Although I write from New England, where Robert Frost harvested blueberries and gathered poetry along with his crop, some of his strongest lines invariably yank me back to Michigan, my native state, and to prosaic thoughts of huckleberries. Suddenly it's Michigan in the early forties again. We are a Missaukee County farm family of seven. Lingering Depression and advancing World War are in the air, and so is the squeak of rusty windmills, the rattle of horse-drawn mowers, the dust of country roads, and the long, receding hooting of trains cruising through McBain on the way to Cadillac. Picking wild berries is the sweetest and best of our vagrant summer pleasures, the fruit sometimes abundant beyond belief. It's a nice way to live. If we had to drive some distance to get them, so much better the berries, so much stronger the mystique.

Although berry picking was a regular part of our family routine, we did not take it lightly, approaching it rather in the rare high spirits of a picnic-in-the-offing, almost a festival, aware that gathering from these unharrowed, unplowed fields was a serious part of our domestic economy. Three or four times a summer, berry picking was our excuse for a full-scale family outing, a respite from the routines of haying and hoeing, and satisfying as a diversion even if the berry crop was a bust. Huckleberries in July and blackberries in August were what we sought, and there were years when my mother canned more than a hundred quarts of them.

These berries grew profusely in the extreme eastern and northern edges of the county, exotic areas known to us simply as the "Plains"—large cutover timber tracts of an earlier generation, the soil too poor ever to have been farmed, now partly growing up to scrub oak, jack pine, and wild berries.

On the appointed day, as determined by the neighborhood grapevine report on the berry crop, or by the calendar, or simply by our success as children at badgering our parents, we prepared for the excursion by tying a ten-gallon cream can on the rear bumper of the '32 Chevy, fastening it securely with recycled baling wire at the bottom and binder twine at the top. That can would hold the berries, for there would be no room inside the car. We equipped ourselves with a recycled Karo syrup pail apiece, and if we were to be gone through midday, my mother and sister prepared a stack of sandwiches. A green gallon jug made of light metal and heavy crockery always went along filled with Kool-Aid.

The blackberry Plains was an hour's drive to the north, the huckleberry Plains an hour to the east. ("Plains," like "oats," was often treated as a singular word.) En route to the Plains we stopped at a grocery store to buy bologna to put into our sandwiches; we also bought chewing gum to shore up our willpower. Gum was rare at home and forbidden in school and was therefore one of the minor attractions of the occasion. The family rule about berry picking was concise: pick first, eat last. The gum made compliance easy, since you can't chew gum and eat berries at the same time. Fathers did not chew gum; they chewed Red Man tobacco. Mothers went without, needing no props to sustain their willpower. Kids went straight for Black Jack gum.

Having secured the bologna and Black Jack, we headed toward the Plains, eventually turning off the gravel road into a twisting, sandy lane, a pair of ruts that had started life long ago as a lumbering road and was now kept open by hunters and gatherers and others similarly unauthorized. We seldom saw other cars in these remote Plains, miles from the nearest farm. We parked the Chevy under a tree, inhaled the pungent air, distributed Black Jack and syrup pails, sampled the Kool-Aid, and then scattered to the four winds in pursuit of adventure and berries—to see what nature was willing to give.

In the huckleberry Plains, the landscape and flora were utterly different from anything in our neighborhood. Here was soil too sandy, too dry to support a decent sod. Young jack pine and small white oak and huge white pine stumps of Michigan's golden timber age flanked intermittent clearings where shadbush, bracken, and sweet fern formed a framework for millions of low huckleberry bushes. Anthills and deer trails and fox dens and hornet nests and bird songs were different from what we knew at home. The rich ambiance of the Plains in high summertime, its eerie silences and wildness, its beloved scents of sweet fern and of hot sun on dry pine needles, still mingles in memory with the taste of warm blue huckleberries.

If the regions near the parking place had been picked over, we would wander far afield—all except my mother. This was one of the rare times when there wasn't a volunteer baby sitter among us older siblings, for we had learned that the fun soon goes out of trying to keep a huckleberry-

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far as the two-year-old from stuffing his face with a cheerful blend of green berries and leaves. Returning with full pails, we often found that Mother, besides baby tending, had filled and emptied her pail already, having found excellent picking nearby. She told one of her secrets: "My mother taught me to pick with both hands, like this. Watch." We watched. Impossible: too many fingers, leaves, bushes to keep track of. "Just work at it; it'll come." It came. But not right away, not that year.

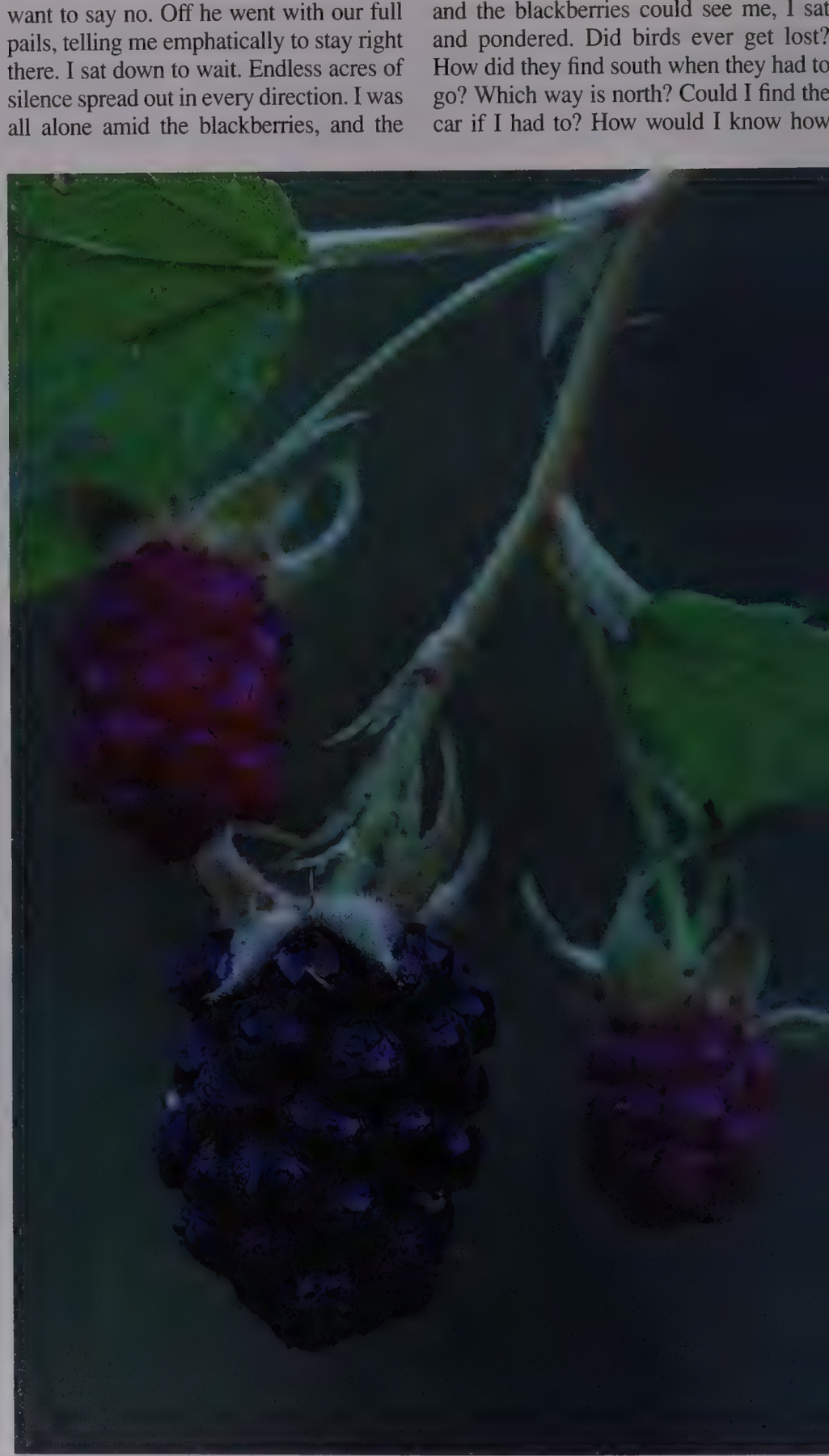
Inevitably, there were times when we went to the Plains and found almost nothing. Once, searching for huckleberries, we were wandering about in circles of frustration among the barren bushes, appalled at the thought of going home to the hoeing fields, when we found some tall bushes loaded down with deep purple berries. This was strange fruit but not forbidden, so far as we knew. We tasted them cautiously, and when we were not struck down in our tracks, we tried more. They were tart and juicy, rather intriguing. We bent the bushes and filled our pails with the strange berries, staining our hands in their juices a deep, dark purple. Just taking what nature was willing to give, we brought the berries home, cooked some up into a sauce, and pronounced the results okay. We then urged Mother to try the definitive experiment, which was a pie.

By this time we were calling the new fruit by a Dutch slang name that, although it probably was not our family's invention, may never have been committed to writing until now—the berries were "smeer-pootjes." (If this name were translated, which I don't recommend, it would come across as something like "little hand-stainers.") Well, smeer-pootjes pie passed our critical palate test very well: maybe not quite up to the scale of huckleberry pie, a very lofty standard, but not bad at all, in a lean year.

It was probably decades later that we identified the plant as shadbush, or Juneberry, a many-specied genus (*Amelanchier*) of the rose family. The chief difference between the New England shadbush and the Michigan varieties is evident only in July: in New England the berries normally shrivel into hard and seedy little beads, tasteless and barely capable even of staining your hand, suitable at best for bird food; but in Michigan, if the rains come in season, the berries often turn into juicy and tasty smeer-pootjes, suitable for ersatz huckleberry pie.

Once my father and I were far from the car, picking blackberries side by side with pails nearly full, when we came upon a berry patch so copious and lush with ripe fruit that it brought tears to our eyes. Here were gifts far beyond what our pails could possibly hold. "I have an idea," said Dad. "The car's quite a ways off—you want to wait here while I go as quickly as I can to empty the pails? Then you can guide me back here by calling." *I* stay *here?* I didn't want to say no. Off he went with our full pails, telling me emphatically to stay right there. I sat down to wait. Endless acres of silence spread out in every direction. I was all alone amid the blackberries, and the berries were all alone amid the vast, mysterious Plains.

What if Dad didn't find the car, just kept on walking? Did he ever get lost? Daniel Boone said that he'd never been lost, but he admitted that he had been bewildered once for three days. I was bewildered already; lost might be next. In the midst of the Plains, where only God and the birds and the blackberries could see me, I sat and pondered. Did birds ever get lost? How did they find south when they had to go? Which way is north? Could I find the car if I had to? How would I know how



Blackberries, ripe and unripe
John Shaw; Bruce Coleman, Inc.

ong I had to wait before I had to do some-hing? The blackberries around me seemed to shrink.

The Plains was a light and airy region: many clearings, few large trees, scarcely a forest, not intimidating. Still, I had no idea at all where I was or where anything was. On the flat and open terrain of our farm community we could always at least tell directions, for we were seldom out of sight of roads and fields that ran north–south and east–west. Now a sense of direction and place, when I wanted to lean on it, simply wasn't there at all. It took about two hours to get through the next twenty minutes. But I mark that remote spot in time as the point where I first began to think that there are two kinds of people: those who have an inner compass and those who do not.

To have an inner compass is to have, for example, a ready answer to the question, Which way *seems* north? Those with the compass have a mental quirk by which the back of their mind is always busy noting directions, making corrections, generating constant low-level interest and information about north-south-east-west. In contrast, those without an inner compass can move for days, even through unfamiliar places, entirely heedless of directions; normally they simply don't care about them. People with inner compasses do care; for them the difference between north and east has a vividness like the difference between left and right.

None of this is based on scientific observation—just careful observation. It's evident that those with an inner compass have a certain advantage and bear a certain burden. The advantage is that the compass is often uncannily right and a powerful ally in finding the way, whether one is mixed-up downtown or wandering through the blackberries in the Plains. The burden is more mysterious. The inner compass may sometimes point the wrong way or even get stuck off course. (I knew a man who moved to a new state and there found his directions mixed. He couldn't fix it. Day after day the sun rose in the south, set in the north: for nine months his world was always distressingly ninety degrees askew. Then he returned to Michigan and had to relearn to trust his intuitions, which were in tune again.) To those without the inner compass, this could not happen, and, indeed, it usually strikes them as a preciously loony problem; they simply consult the objective facts about directions and make the mental correction.

To psychology and sociology I leave it to discover, if they can, how much of this is true; and to philosophy to help resolve the quandary, if it can, of what facets of the inner compass belong to nature and what to nurture.

Very faintly, my father's distant voice drifted from the vastness into the directionless patch of Plains where I kept vigil with my blackberries and my thoughts. I bellowed in response and waited. Silence. Exultation and despair. Then another call, then another, and then I guided him in; and then the blackberries, which had shrunk to insignificance, swelled out again to luscious fullness. We quickly filled our pails once more, and then we tossed away our Black Jack and Red Man and filled our stomachs. Those blackberries loom in memory as being as thick as a man's thumb and almost as sweet as jelly, the standard against which I forever measure blackberries. When we were ready to go, Dad, pointing, said, "We'll head off that way, just a little to the right of the sun, and when we get to the third clearing we'll bend more south." We did that, and the route led directly to the car.

From that day I began to pick up on the fact that fostering one's own compass involves drawing habitually on all kinds of data, slant of the light and shape of the terrain among them, and on cultivating in familiar territory, and inadvertently at first, a lively roster of mental habits, mental mappings. In time it became a point of pride among us—my father, brothers, friends—to work our way through strange forests without becoming disoriented, a skill that can become a sixth sense of forester and hunter, or even of the wandering berry picker. Those of us who grew to adulthood on a mental landscape that nurtured an inner compass have probably lost the ability to shake it off; everywhere it shadows our steps, unforced, like a gift of nature, whispering directions, quietly pointing.

We were in no hurry to leave the rich-giving Plains. We had filled our containers, filled our stomachs, nearly filled our souls. When we got home we were comfortably behind schedule, a reminder that the day had been unusual. By the time the chickens were fed and the eggs gathered and supper prepared and consumed and the cows milked and the milk separated and the calves and pigs fed and the dishes done and the table cleared and the toddler packed off to bed, it was dusk. But fresh berries do not keep, certainly not in a hot, closed cream can, so they had to go into the canning jars tonight for processing tomorrow. Blackberries would go almost directly into the Mason jars with only the most cursory sorting needed; but huckleberries required more attention, since young, unskilled two-handed pickers also collect refuse with the berries. We had to sort the good fruit from the chaff.

Imperceptibly, these excursions off the home grounds became parables for us, inadvertent and unrecorded as such, but not without effect—tokens of the larger adventure of life. The Plains that seemed so vast and giving, so unbounded, so alive with the scent of mystery, yielded a sweet and simple berry harvest, certainly, and something far beyond that too. There, if anywhere, were intimations that somewhere we might gather where we had not sown; there too were hints of uncharted territories of the future where we could no longer take our bearing from serene and cozy farmscapes but would have to extract it hopefully from the scattered data in a larger, wilder world, from the source and direction of light, and from an inner compass, probably nurtured unconsciously, but yet mysteriously aligned, one might hope, with the encompassing moral order.

But we had to get the chores done. That accomplished, we assembled around the kitchen table, dishpan heaping full of huckleberries as centerpiece, each of us equipped with a flat tray, its bottom covered one tier deep with berries. The kerosene lamp above the table, the kitchen's only light, was suspended by an adjustable chain; so we pulled down the lamp until it brooded low over the berries, until its round glass globe had combed all the superfluous light down off the kitchen walls and gathered it on the table directly in front of us all. Seated in the pale glow of that family circle, heads bent over the berries, arranged in our best Norman Rockwell pose, we might have appeared to be praying. But no; that we had done already. We were moving the berries from one vessel to another, from cream can to dishpan to sorting tray to Mason jars, performing the last of the simple ceremonies of the harvest, carefully picking over the entire batch, tray by tray, getting the last fragments of the Plains out of our berries. Getting the Plains, temporarily, out of our system, too. Tomorrow would be hoeing and haying again. But we were also closing in on the next day's huckleberry pie. It's a nice way to live.

Ronald Jager, a former professor of philosophy at Yale University, is currently a free-lance writer living in Washington, New Hampshire.

Food for Thought

Act globally, think locally

by Roger L. Welsch

I know you've seen more than enough about global warming. My editor at *Natural History* told me so: "Welsch, I hope you're not planning to do something on global warming. Our readers have seen more than enough about global warming." That is like telling someone not to think about the word *elephant*—for days, the poor guy will think of nothing but *elephant,* right? So for weeks, my mind has been locked onto global warming. Or cooling. And there's the problem. The question is not, Is it getting warmer or not? No, that would be easy. What complicates matters is that some credible scientists say the planet is getting colder. Well, great. Are we going to have high tides in Cheyenne or do we have to think about Atlantis as an NFL expansion team? Or will we have to deal with both disasters at once? Science has never looked worse.

Three of my favorite locals were recently gathered in Slick's Big Table Tavern up in town when I saw pass before me a metaphor for the confused readings of our global thermometer. The issue under consideration in the Dannebrog think tank was, What has been the greatest advance in science during the past century? Slick, a philosopher, spoke first: "I think the transistor will eventually be recognized as the greatest advance in science during our century because it has changed so many things in our lives—travel, information dissemination, scientific calculation, data storage and retrieval, publishing...."

Those in attendance at the Big Table thought about that for a while with such attention that if you leaned forward, you could smell mental bearings overheat. Then Woodrow, a plumber, spoke up: "Me, I think the greatest advance in science during this century has been space exploration. It has taken us away from worrying only about the small matters of village and state and has forced us to think instead about the earth as a common home for us all in a vast emptiness."

Not bad, for Woodrow. The table fell still. More thinking, more overheated brain bearings.

Then Lunchbox cleared his throat and we all turned to him in anticipation. Lunchbox is an auto-body repairman and spends a lot of his time waiting for lacquer to dry, during which time he thinks, so his opinions are prized. "I think," Lunchbox said, "the greatest scientific advance of the twentieth century is the thermos bottle."

Slick spoke for us all when he sputtered, "What? The thermos bottle? All it does is keep stuff hot or cold!"

"Yeah," said Lunchbox deeply, "but how does it know?"

Obviously, the problem(s) of global warming/cooling could use a little of Lunchbox's thermos bottle theorizing.

The next day Slick said that he had done some scientific legwork, and instead of finding an intellectual Ararat, he was now as much at sea as all the other scientists. He reported that he sold his first gin and tonic of the year in early April—a full month earlier than usual—but over at the grocery store Kerry reported he was still selling hot chocolate mix well into June. Even organisms closely affected by changes in our climate seem uncertain about the direction of those changes.

For my part, I thought I could contribute something by looking into my extensive archive of American folk wisdom. If the confusion in this debate is some thing new, I reasoned, that might signa something out of the ordinary is takin place—possibly change, maybe ever heating or cooling. But I found that mete orological contradiction is anything bu new. Almost twenty years ago an old pio neer remarked to me, "Sure has beer hot...for being so cold." And it's beer nearly forty years since I first heard the ol standard about the time the temperatur dropped so rapidly, and lakes and river around here froze so fast, the ice was stil warm.

On the other hand, it was only last yea that a Sandhills rancher gave me food fo thought when he reported, "It wasn' nearly as hot this past summer as ex pected, but then no one thought it woul be." No help to be found within tradition it seems.

Not at all easing the ponderings of thos of us who care about such things are th deliberate efforts on the part of medi weather forecasters to muddy climatologi cal waters. When it's warm enough—say 102° in the shade—meteorologists (wh curiously never report the status of mete ors) talk about the "discomfort index being 116°. They say that when you con sider all sorts of other factors like humid ity, wind speed, and the price of Fudg sicles, it feels like 116°, which is lik saying, "Don't think about the word *ele phant,* and whatever you do, don't con sider global warming." Then, six month later, when the temperature is –16°, mete orologists (still with nothing to say abou tektites and such) tell us that the "win chill factor" is –46°. Never mind what th thermometer says; when you add in th

humidity, wind speed, and price of firewood, we're as miserable as if it were actually –46°. That's not science; that's congressional accounting. Why not calculate the wind chill factor in August or the discomfort index in February and make us all feel just a little bit better about things instead of a little bit worse?

By now you know that I'm not one to leave you hanging out there wondering. I have an explanation for all this. As is so often the case, the confusion here stems from scientific specialization: scientists working in climatology have spent far too much time in front of a computer and not nearly enough time in an easy chair watching television. The solution for all this apparently contradictory evidence of global warming and global cooling was presented on television, on every channel, in detail, if the scientists had just taken the time and trouble to watch the evening news: ketchup is no longer America's number one condiment; salsa is. And there you have it.

The meteorologists were close, but no cigars. Humidity, wind, carbon dioxide, cloud cover, volcanic ash, rain-forest destruction, ozone layer, methane, Ray Charles and the Rayettes…yes, they probably all contribute to some degree to global warming or cooling. But the fact is—and you can take my word for this—they are of only modest significance in comparison to the Salsa Factor. Whatever the weather does now is of no consequence. America is warming up—from the inside out.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

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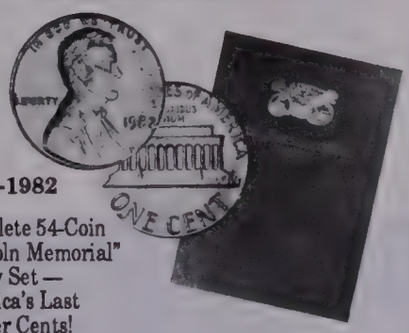

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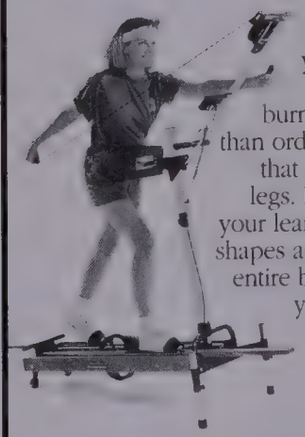

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In South Africa's lowveld, a giraffe cow feeds on the flowers of a knobthorn acacia. Because female giraffes lower their necks to feed and males reach to the highest branches, the two sexes rarely compete for the same food.
Lex Hes

Winning by a Neck

Some trees succeed in life by offering giraffes a meal of flowers

by Johan T. du Toit

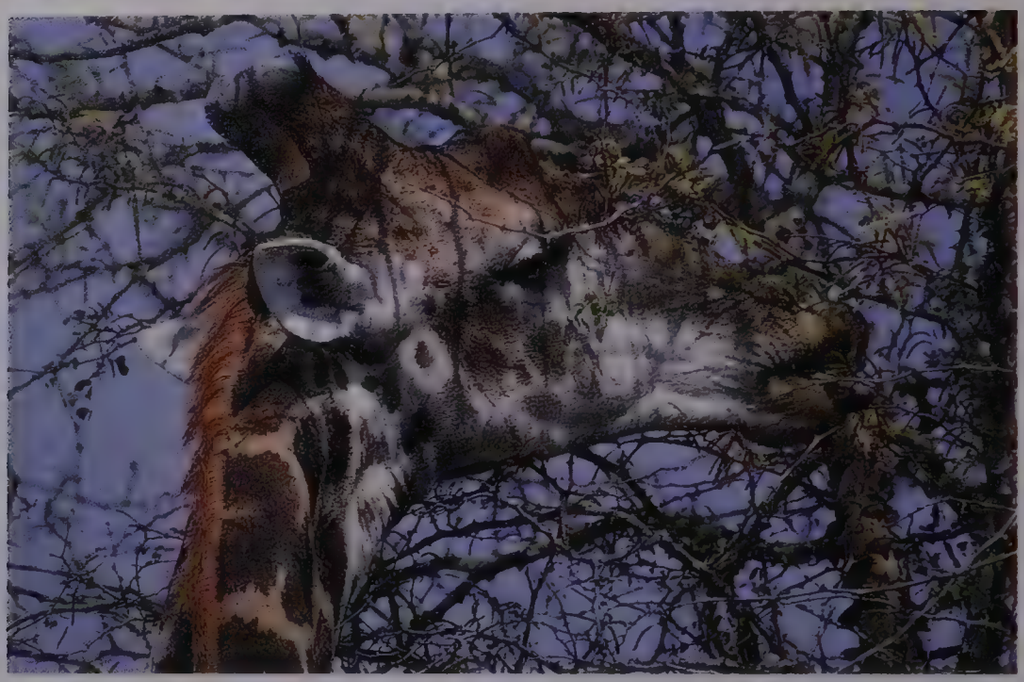
A person has time to think when sitting in a parked car, waiting for someone. I often found myself in this situation while studying the feeding patterns of giraffes, kudus, impalas, and steenbok in South Africa's Kruger National Park. On a typical day, lunchtime music was playing softly on my radio, and cicadas shrilled in the grass. The landscape was dry and dusty, except for the rivers in the distance, which were visible as bands of green vegetation that stood in bold contrast to the brown hills. I might have been watching one of my study animals, perhaps a giraffe cow ruminating in the shade of a knobthorn acacia. Beneath a veil of creamy white flowers, the gray limbs of the tree shimmered in the midday heat. The giraffe, her ears laid back and her eyes half shut, chewed steadily on acacia flowers.

This scene is typical of the late dry season in the lowveld, South Africa's expanse of semiarid savanna. The lowveld receives only twenty-four inches of rainfall each year, mostly in the austral midsummer from November to February. During this short wet season, plants sprout new leaves and many burst into flower. Antelopes and many other medium-sized herbivores calve at this time to take advantage of the plentiful food. With the onset of the dry season, however, conditions begin to deteriorate as soil moisture evaporates and seeps into the folds of the landscape. By August, most trees are dormant, standing bare over the brown earth and brittle grass, and most large herbivores have moved downslope to riverbanks where they can still find some green leaves to browse on. The animals must survive several more hot, dry months before purple-gray rain clouds arrive. Ribs and pelvic bones will protrude farther before the green flush of the next rainy season.

During my three years in Kruger National Park, I spent my days tracking the movements of my study animals and recording their choices of habitats and food. Many interesting results emerged as my work proceeded, but perhaps the most remarkable was the relationship between giraffes and the knobthorn acacias (*Acacia*

Mitch Reardon; Photo Researchers, Inc.

Moving among the branches of a knobthorn acacia, below, a giraffe easily crops the bottle-brush flowers, which are poorly defended by short, knobby thorns. In contrast, a giraffe feeding on the small pompon flowers of Acacia nebrownii, *right, must contend with long, sharp thorns.*
Julie Cox



nigrescens), common trees of the dry plains and ridges. Toward the end of the dry season, giraffes are lured away from the riverine vegetation by the knobthorn flowers. Borne in clusters on the ends of branches, knobthorn blossoms are easily cropped by giraffes as they roam from tree to tree, and provide them with up to a quarter of their food during August and September, when the trees are in full bloom. Other browsers lack the giraffes' height advantage and are unable to reach flowers on most knobthorn trees, although I often saw impalas scavenging dead flowers that had fallen to the ground.

At various times of the year, I observed giraffes feeding on the flowers of other tree species, but these provide little food compared with the knobthorns. I found it odd that only the knobthorns produce such an abundance of flowers at a time when the giraffes need them most as food. In the dry season, the survival of plants depends on adaptations that protect them from browsers. So why hadn't the knobthorns evolved defenses to protect their flowers? Wouldn't the loss of so many flowers reduce the trees' ability to reproduce?

As my research progressed, I began to wonder if the relationship between giraffes and flowering knobthorns might not be as one-sided as it first appeared. Perhaps the giraffes were paying for a palatable meal by carrying pollen between patches of flowering knobthorns. This possibility became increasingly plausible as I learned more about the reproductive biology of African acacias.

Although the pollinators for only a few species of African acacia have been identified, the general assumption has been that insects perform the task. (The pollen grains of acacia trees are too large and heavy to be effectively dispersed on the wind. Birds and bats are unlikely pollinators, because the knobthorns do not provide the nectar they seek.) Therefore, on the plains of a semiarid savanna, it makes sense for a tree to flower in the wet season, especially after each rainstorm, when flying insects that are likely to transfer pollen are most active. The umbrella thorn (*Acacia tortilis*), one of the most common trees in my study area, follows this pattern, flowering sporadically in the wet season. Each flowering is triggered by recent rain so that the same tree may flower several times a season.

During the hot dry season, however, bees are rarely found far from water; I often saw swarms of them along the edges of stagnant pools or on damp sand in drying riverbeds. It makes sense for riverine trees to flower in the dry season when competition for insect pollinators is low and bee activity is restricted mainly to the same habitat as the flowering plants. Indeed, Kipling's fabled fever trees (*A. xanthophloea*) occur only along rivers and bloom in the late dry season, when their golden "pompon" flowers sweeten the air and the riverine canopy hums with bees.

The distribution of flowering knobthorns, however, does not appear to make much sense. Although they also flower late in the dry season, they are rarely found along rivers and are often miles from surface water—and bees. On the hot, arid plains, their flowering canopies are striking to the eye, but they are neither fragrant nor humming.

Based on the general appearance of their flowers, taxonomists divide the African acacias into two different groups. One, which includes the umbrella thorn and the fever tree, generally has bright golden or orange-yellow pompon flower clusters and is probably pollinated by insects. These acacias flower at times when flying insects are active in their habitats, their fragrance and colors attract insects, and their spiny thorns protect their flowers from browsing herbivores. The other group, which includes the knobthorn, has flower clusters that resemble slender bottle brushes and do not seem to be as well adapted for insect pollination. In fact, the knobthorn's pale flowers fit the tendency for flowers pollinated by mammals to have dull colors.

Bats are the most common mammalian pollinators, but within the last decade, a number of small, flightless mammals have also been found to transfer pollen. For instance, Delbert Wiens, a biologist at the University of Utah, found that the flowers of the South African protea are pollinated by rodents (*see* "Secrets of a Cryptic Flower," *Natural History,* May 1985). Mammals are covered with fur or hair, which is good for collecting and carrying pollen grains, and because they are so much larger than insects, they can carry more. Their biggest disadvantage is that most mammals cannot fly, making them poor cross-pollinators. Efficient cross-pollinators must have easy access to flowers in the tree canopy and the ability to travel directly between widely distributed plants of the same species. Giraffes meet all these qualifications. While browsing fifteen feet above the ground, their heads and necks become covered with pollen as they shake branches and brush through clusters of blossoms. (While inspecting trees on which the giraffes had fed, I inadvertently collected pollen on my forearms.) Giraffes are capable of traveling more than ten miles a day between stands of flowering trees.

All plants pollinated by animals have to pay a price for the service, usually in the

For a meal of knobthorn flowers, below, giraffes may travel miles across the plains. Right: To reach the upper flowers, a male giraffe uses his tongue to extend his reach by almost a foot.
Norman Owen-Smith

form of pollen and nectar, which are rich in energy and protein. Because giraffes operate on a larger scale, their reward is whole flowers—the one disadvantage to the tree of giraffe pollination. Their potential as pollen vectors remains academic unless the benefits of pollen transfer override the drawbacks of flower loss.

Browsing by giraffes is less of a threat to the reproductive fitness of flowering knobthorns than might be imagined, however. Despite swarms of flying insects around the flowers of some species, African acacias are noted for a particularly low ratio of seed pods to flowers. Many of the flowers may never get fertilized, but another reason for the small number of pods may be that most, and possibly all, African acacia flower clusters are mixtures of bisexual, male only, and sterile flowers. Some botanists have suggested that large numbers of male and sterile flowers could function as petals and are simply there to attract pollinators. The loss of sterile flowers to giraffe browsing is of no consequence to the reproductive fitness of the acacia trees. Nor is the consumption of male flowers if their pollen is transferred in the process. Furthermore, since all the knobthorns produce flowers simultaneously, the giraffe population (which is limited by the scarcity of food during the rest of the dry season) cannot consume a significant fraction of the female flowers in the short time that the trees bloom.

Even though an animal may be capable of transferring pollen, it is not necessarily a reliable pollinator. The animal must visit the plants regularly, as part of its usual feeding pattern. In central Kruger, this is precisely the case. Knobthorns provide giraffes with much more than flowers. During the wet season, knobthorn foliage is the staple diet of giraffes, making up more than 40 percent of their annual diet. The intimate link between the two species is reflected in the distribution of giraffes and knobthorns in the park, which can be nearly superimposed upon a map.

Perhaps the strongest support for my suggestion that giraffes pollinate knobthorns is the trees' lack of defenses. If giraffes browsing on flowers were harmful to the reproductive success of knobthorns, there would be selective pressure for the evolution of an effective defense. Witness the well-defended pompon flowers of the umbrella thorn, a species that is pollinated by insects. Borne on short stalks, the flower clusters lie close to the branches, between long and formidable thorns. In contrast, the knobthorn's bottle-brush flowers extend beyond the protection of the trees' prickles. Nor are the knobthorn flowers defended by noxious chemicals. In contrast, I never saw a giraffe even nibble at the spectacular bright yellow flowers of a *Cassia abbreviata*, a tree related to acacias, even though they are easily accessible, suggesting that they may contain a particularly unpleasant toxin.

While I still lack definitive proof that giraffes are pollinating knobthorns, there is solid evidence for the coevolution of some acacias and large African herbivores. The seedpods of the umbrella thorn are aromatic and nutritious, so when they are shed in the dry season they are avidly sought out by impalas, kudus, steenbok, and other herbivores. Their hard, thick coats protect the seeds from damage as they pass through the herbivore's gut, and the seeds are ready for germination when they are eventually deposited in dung some distance from the parent plant. If co evolution between large herbivores and African acacias could result in an efficien system of seed dispersal, I see no reason why it could not lead to efficient pollen dispersal as well.

Traditionally, pollination by animal has been regarded as the exclusive domain of small species that fly. Only within the last decade have some small flightless mammals proved to be pollen vectors, and these discoveries were initially considered bizarre. Now I am really bucking tradition by suggesting that some acacias may be pollinated by the tallest living animal. must point out, however, that this story represents only the first step of scientific inquiry: the formulation of a testable hypothesis. My next step will be to test whether making knobthorns inaccessible to giraffes will significantly reduce production of knobthorn seeds. This will not be easy, however, because any barriers erect to exclude giraffes must be strong enough to avoid destruction by elephants which can wreck just about anything—especially fences. But the effort will be worthwhile if it confirms that the knobthorn has evolved a pollination system that relies on the world's tallest animal. □

A Kurdish girl does some washing, Iran
F. Jackson; Robert Harding Picture Library

Moonrose

Watched Through a Sunny Day

by Erika Friedl

Child labor within the family economy—standard practice in most parts of the world—is underreported, especially for little girls whose work at home is easily downplayed as unimportant. For girls like Moonrose-Goli, who lives in a village in Iran, childhood is packed with chores; playing and dreaming happens in stolen moments between baby-sitting and carrying water, between washing and running errands as a servant to everybody. Skinny, with quick eyes and rough hands, running fast on tea-and-sugar energy, the girls try to discharge their responsibilities without proper authority, strength, help, or recognition. Watching such children in Iran and Turkey, I wonder where they get the endurance and the good humor that sees them through their loaded days. I wonder how much of the work needed to sustain families the world over is contributed by those whom we, ethnocentrically and without much reflection, label "vulnerable" and in need of care and sustenance.

There isn't a rose in sight where Moonrose lives: not in the large, dung-strewn courtyard, not in the alleys along the water channel, and not on the sun-bleached, brown-mottled hills behind the village. In spring, the hedge roses around the orchards—small, nearly white blossoms on prickly stems—bloom for a short while, but they wilt quickly and don't smell like much. Yet Rose is a common name for women in the village. Moonrose is Mahgol; everybody except her mother calls her Goli.

Goli is a tiny flower, nine years old, small, scrawny, with narrow-set brown eyes and a long nose. Her pointy face is framed by a pinkish gray scarf that mats down her many dark, thin braids. She has just finished third grade. Goli's mother is up somewhere in the greenish haze behind the gray rocks of Snow Mountain, gone for the summer with the sheep and goats. Her father makes the four-hour trek several times a week along the steep trails radiating out of the village toward the cool valleys and high plains where the herds are in pasture camps. He is on his feet from well before dawn until after nightfall, day after day, all summer long.

Goli's grandmother went up with him a few days ago, to help Goli's mother at the birth of a sixth child. Goli, all skin and bones and sinew under her tattered gray sweater, long, heavy skirt, and dark, dusty pants frayed at the ankles, was left at home to take care of her father and her brothers all by herself.

The family's mud-brick living quarters

Washing cooking pots at a well, Iran
Reinhold Loeffler

A Kurdish girl makes a fire for tea, Turkey
Reinhold Loeffler

have been built atop barns and sheds. Goli's father's two rooms are between his brother's rooms and her grandmother's room, which doubles as a storage space. A flat, extended dirt roof shades a narrow porch running along the front of the house. Beyond it, a wide, uncovered veranda (roof to barns and sheds below) stretches to its unprotected edge some ten steps away. In the shade of her porch, the wife of Goli's uncle, her eyes closed, weak and tired as usual, leans against the gritty wall and rocks a cradle. Two of Goli's little cousins throw rocks at chickens in the yard. The midsummer sun scorches the air, bakes the walls, the dirt floor.

Goli almost burns her hands on the aluminum tray propped against a roof post; she needs it to take a heap of dirty clothes down to the water faucet. With her foot, she pushes the tray into the shade to cool while she shuffles next door in her father's large, plastic flip-flops. "I need soap from Grandmother's room," she says to her half-dozing aunt. "Give me the key." Without opening her eyes, the woman finds it in the inside pocket of her red velvet jacket. "Wash the baby's rags too, dear, will you?" she asks. Goli pulls a face of disgust, but the woman does not see it. When Goli brings back the big pile of wash she carried to the water, the sun is high, her back aches, her arms are red, and the skin on her fingers is wrinkled.

Goli is sitting on the floor in the shade of the roofed porch outside her father's kitchen-living room, bent over a mound of rice on a shallow aluminum tray. With a flick of her fingers she scatters a handful of rice kernels toward her on the silvery surface, picks out little stones and seeds, chaff and dirt, and heaps the clean rice along the wall of the tray. One of her cousins, a square little boy a couple of years younger than she, with a runny nose, dirty hands, and dirtier feet, squats on the other side of the tray, helping her. When Goli turns her head to call his sister away from the dangerous edge of the veranda, his fast, grimy fingers grab a handful of clean rice from Goli's side and drop it on his small pile. Goli has seen it. She laughs, pinches his hand, kicks him with her foot. "Rascal," she says. "Work right or else I'll kill you." On his feet in a flash, the boy slaps his hands hard into the hill of rice. The dry kernels scatter all over, the boy runs out into the sun. "Get lost," Goli shouts, "I'll kill you for sure."

Holding her uncle's baby under his armpits, Goli swings him slightly. She sits with her back pressed against a big sack of fleece on her uncle's porch. "Oh, baby dear, oh, little boy," she hums. He smiles. Goli moves him faster, lifting and dropping him jerkily, chanting: "The moon is so bright, the moon is so bright, the wolf will get the shah's sheep tonight. The moon is so bright, the moon...." The boy, red faced, dangling limply, head crammed between his squeezed shoulders, screws his eyes shut and whines. "Don't like it?" Goli asks, swinging him sideways and panting from the exertion. He whines louder. "Listen to this: 'Hosein dear, Hosein dear, beets are gone, turnips are here'...well?" The baby is crying now; his cotton pants have slid down and his ragged T-shirt is bunched around his neck. Standing him on her lap, Goli slides him back into his pants and then props him against her knees. "Don't cry, don't cry dear, dear," she says, touching his chin, his lips, his chin again to make him smile, but he does not stop crying. She catches a hen and slaps the baby's hand on its brown back. "Hit it, hit it," she tells him. As the cackling and flapping hen pecks at his hand, he starts crying bitterly. Goli lets go of the hen and cradles the baby in her arms, rocking him gently. "Lalai, lalai," she sings, as if putting him to sleep. As he quiets down, she pulls his cap up, smooths his shirt, and jingles the amulets—beads, a tiny iron spit, a smooth, polished salt crystal—pinned to his shirt. She waves flies away from his watery eyes, wipes his snotty nose with her skirt. He stops crying, and she holds him still, studying his face intently.

At the water faucet in the alley, Goli washes the picked-over rice in a battered aluminum pot. A neighbor girl fetches water in a white plastic can, and one of Goli's aunts scrubs a big copper pot with sandy mud from around the cement-encased faucet. Goli swishes the rice around in the milky-gray water—back and forth, up and down, round and round. The smooth, pearly-hard grains trickle through her fingers. Straw floats to the surface, and Goli skims it off before she drains the dirty water, tilting the pot

A girl milks as her baby sister sleeps on her skirt, Iran
Reinhold Loeffler

Staggering from the weight of water buckets, Turkey
Reinhold Loeffler

ever so carefully. The neighbor girl pours fresh water over the rice, and Goli again swishes and sloshes and drains. Straightening up, she yanks her scarf down over her face and then back over her forehead in a swift, practiced movement that packs her untidy hair under the washed-out pink buds on her scarf.

She picks up her pot for a last rinse, turning to the faucet jutting out of the chipped and crumbling concrete block. The faucet is tricky: turned a little too low or too high, the water will squirt every way but down. Impatient or just unmindful, Goli turns the wobbly brass lever a notch too far and is instantly doused from her face down to her knees. "Watch it, girl," her aunt cries, leaning away from the jet of water. Goli clonks the pot down on the muddy grille and wipes her face with her arms. "Death and ashes on my head!" she cries, jumping up and down. "You'll catch cold," warns her aunt. Goli is still jumping up and down. "I am cold, I am wet, a water sack is on my back," she chants, flapping the frayed sleeves of her ribbed sweater. She picks up the pot and, [illegible] to balance herself, shuffles up the steep, short stairway across the channel to her house. "I am cold, I am wet, a water sack is on my back," she chants loudly to the rhythm of her shlap-shlapping shoes.

Crouching in front of the fireplace, Goli coaxes a fire of brush and oak branches. The fireplace, a curbed niche at the foot of a mud-brick wall, is black with the soot of years. Heavy gray smoke billows up from the brush. Goli leans forward, blowing with all her might, cheeks full of air, like bellows. The smoke is choking her and burning her eyes although she has them shut tight. She coughs and wipes her eyes. The fire will not catch. She has carried the wood up from the shed below because there was no gas in the bottle under the gas stove in the kitchen. With a deep breath she blows a long, sustained stream of air, ending with some fierce huffs, which make the gray ash of a dead fire fly up and settle on her head and arms. She gets up and brings a bottle of kerosene from the kitchen. Standing back a step, she pours the kerosene over the smoking wood and puts the bottle into a niche in the wall. Then she lights a match and drops it onto the smoky pile, shielding her face with her arm. The evaporating kerosene explodes in a high yellow flame. The wood is on fire.

Goli's younger brother and her cousin are ambling across the veranda. "I want bread," her brother cries, "I am hungry."

"Get lost," Goli says crossly, without looking up. Leaning against the porch beams, the boys watch the fire and Goli as she pours the washed rice from the aluminum pot into a copper cooking pot. The copper is black from the smoke of countless fires; inside, it is tinned, silver bright. Goli fetches a water kettle from the kitchen and swings it toward her brother's belly. "Go get water," she tells him.

"No," he says, "I want bread." Goli shrugs as if she never expected compliance anyway and leaves for the water faucet. The little boy runs after her, hammering his fists into her back. "Bread, bread," he yells. Goli ignores him.

Back with the dripping kettle, her brother in tow, Goli rinses the last grain of rice from the aluminum pot into the cooking pot. The fire is dying again in smoke; kneeling down, she blows life into it vigorously. "Black death on the damn thing," she mutters, but then turns and unleashes her fury on her brother, who is pulling down her scarf. "Beat it or I'll thrash you!" Her brother disappears into the kitchen and comes out with his hands full of bread. He has ripped it from the neatly folded, paper-thin flatbreads that are stored there. Goli watches the fire. Behind her back, her brother swipes the matches she had left on the floor—matches are scarce, a prized possession. She notices both thefts as she is about to take the kerosene bottle back to the kitchen. But a furious yell and a streak across the wide, sunny veranda in her bare feet are futile: the boys have vanished.

With a black smear along the side of her nose, a hot, flushed, and disheveled Goli drops an iron tripod over the low-burning wood and heaves the cooking pot onto it. She pours water from the kettle over the rice, and more water after yet another trip to the water faucet. She pours a handful of salt from a yellow tin can into the rice pot, stirring it slowly with a long-handled, flat aluminum ladle. While the rice is popping up and down in the bubbling water, Goli takes a stubbly broom from a corner and sweeps the breadcrumbs out toward the edge of

Carrying a younger child, Iran
Mohammad Kapoorchal; Sipa Press

the veranda, where a small hen is leading three chirping chicks. Her agitated clucking at the bread brings two more hens and a rooster running. The rooster and the hens are much faster than the chicks. Goli throws dirt at the hens, but it scares the little chicks more than the hens. They peep and run and flap their tiny yellow wings. Goli shrugs her shoulders. "Little ones are always hungry," she says.

Her uncle's wife helps Goli strain the half-cooked rice through a sieve. The chickens are waiting for the few spilled rice grains. Goli spoons a ladleful of yellow, coarse cooking fat from a big square tin can into the empty copper pot on the tripod again and pours the rice back in, adding a bowl of cooked lentils. Her little cousin is yanking at Goli's skirt, whining for rice. Goli ladles some back into the sieve for her. "It is not cooked yet, you'll get a tummy ache," she says. Despite her own warning, she scoops a ladleful out for herself, blowing at it and then swallowing fast, while the toddler sits at the kitchen sill, out of the range of heat from the fireplace, eating with both hands. "Sit down right, eat right," says Goli. The little girl licks her fingers.

Goli sprinkles water over the rice and lentils, spreads a singed rag over the pot, then presses the lid down tightly over the cloth. Carefully, she ties the corners over the lid so that the rag does not burn. Surveying the scene, she collects the sieve, the ladle, and the aluminum pot and wipes her face with her skirt. Then she climbs a few feet up the wall, using rough mud bricks as holds, and shouts over the top: "Hoi, Fateme, hoi, hoi, I'm ready, hear me?" And from somewhere beyond, Fateme answers, "I'm coming."

Under an apricot tree in one of Goli's father's gardens, Goli and Fateme squat face to face. Propped against the tree are two woven backbags filled with grass. Two sickles lie in the withered weeds. The afternoon is dry, dusty, heavy with hot, shimmery heat. For Goli and Fateme, the visible world ends at the dark, high brambles around them. It is filled with sunlight, filtered and softened by dense leaves above them, with the twitter of sparrows in the tree, the irritating buzzing of countless flies, the gurgling of water from an irrigation ditch nearby. On the almost bare ground between them is a handful of smooth pebbles for playing *haftuk*. Fateme holds a pebble in her right fist. "Watch it," she says. She throws it straight up in the air, following it with her eyes, while her hand picks up a pebble so fast that it is ready to catch the first one as it is falling. Next, Fateme throws up two pebbles, grabs a third, catches both; at the third move, one of the three pebbles in the air spins sideways and falls to the ground uncaught. Now it is Goli's turn. Goli, mouth puckered in concentration, catches one, two, three, four pebbles. At the fifth turn she misses a catch. "The sun blinded me, it was the sun!" she cries.

"Lies, lies, you just missed," says Fateme, raking in the pebbles. Goli throws her pebbles to the ground and gets up. "Let's go," she says. Staggering a little under its weight, she heaves a sack onto her back by its straps. Fateme throws a few more pebbles into the air, misses, abandons the game. Goli has already climbed over the hedge.

Walking along the path between hedge roses and blackberry hedges and the irrigation channel, the girls cut some grass growing in clumps here and there along the water. When they reach the village, the minty smell of the cut grass on their backs and in their arms blocks the pungent odor of trampled dust hanging in the alley between the hot walls.

Next to the kitchen door, Goli's father and elder brother sit on the threadbare rug Goli has spread for them. On a small, shiny tray between them is a bowl holding lumps of sugar and two small glasses on gold-rimmed china saucers. Goli's father pours tea and water from a dented yellow enamel teapot and a water kettle, black with burned-in soot. The man and the boy had driven their donkeys back from the nearby wheat fields,

loaded with straw stuffed in huge net bags. By the time they had unloaded and come upstairs, Goli had steeped the tea and put the tray on the rug. Now she sits on the floor a little away from her father, leaning against the house bricks, feet tucked under her skirt, looking at the sunburned faces of her father and her brother, the straw in their hair, the dusty jackets. She watches them slurp tea from the saucers. While her father refills the glasses from the pot and the kettle, her brother, without looking up, says: "Get me water." Goli fetches a small leather bag with an aluminum cup over its neck from the far side of the porch, filling the cup on her way back. The boy takes a sip and spits it out behind him. "Warm," he says with a grimace, pouring the rest on the floor. "Get cold water." Goli, walking across the wide veranda toward the stairs, empties the leather bag with sweeping splashes. Little dust clouds burst where the water hits the dirt floor. The men do not wait for her, however, but stop to drink the water from the faucet on their way out of the house. Goli watches them drive the two donkeys out through the open door on a trail of golden straw. Then she sits down by the teapot and pours herself a glass of dark tea, adding hardly any water at all. She pushes the saucer off the sugar bowl, where her father had put it to keep the flies out, and pops two lumps into her mouth before taking a big sip of tea. She pours more tea, drinks it over more sugar, pours another glass and yet another, until the pot is empty and the sugar all but gone.

From the kitchen door, Goli yells at her little girl-cousin squatting near the edge of the veranda. "Black death, [illegible] brat, nothing but troubles all day long, [illegible] an evil spirit get you. What are you [illegible]here? Sarah! I'll kill you!" she shout[illegible] tell your mother for sure. Woe to me, [illegible] on my head for having to watch such [illegible]." The little girl stirs [illegible] a pi[illegible] chicken shit with her [illegible] I am [illegible] bread dough," she [illegible] leaves me [illegible]."

"Ferry, filthy," [illegible] yells, pushing her backward. "Ugly br[illegible]ook at your hands,

A young woman supports a load of washing on her head as a child carries a skin bag full of water, Iran
Reinhold Loeffler

Taking care of ducklings, Turkey
Konrad Wothe

look at your face!" She yanks her up by her shoulders, and half lifting and half pulling her by her left arm, and staggering under the weight, drags her down to the water, accompanying the child's screams with a stream of curses. At the faucet, she clamps Sarah tightly between her legs while she scrubs her face, hands, and arms until they are red with cold and both she and Sarah are drenched.

A little later, picking dry clothes from the line, the wall, and the ground, Goli finds Sarah huddled with two other little girls in the wide shade of a wall, mixing earth with water from a long-spouted, green plastic toilet can. Goli stops and looks down at them over the big pile of wash in her arms. One of the girls is forming small mud balls between her hands. On a flat rock, Sarah is rolling out a ball of mud dough with a twig stripped of bark. "Dear, dear, my dough is ripping," she mumbles, patting it into shape with her hand. Goli shifts her feet as if to squat down but then thinks better of it. "It needs more kneading," she says from up high. "Don't you touch my dough," Sarah says. "Go away, your hands are dirty." And Goli slowly turns and leaves.

In the kitchen, dim light falls on Goli from the half-closed door and a small window set deep in the thick mud-brick wall. She kneels on the gray gypsum floor, bent over a heap of flour in a large round basin. Fateme slowly pours water from an aluminum pitcher on the flour. Goli, sweater sleeves rolled up above her bony elbows, mixes dough from the flour and water. She had measured twenty double-handfuls of wheat flour into the basin, and she had gotten Fateme to help her. Making dough and baking bread requires the strength and experience of a woman. But Goli, a helper to her mother at this chore for a long time, has baked alone before this summer, and anyway, what choice was there? Barely enough bread was left for the morning meal.

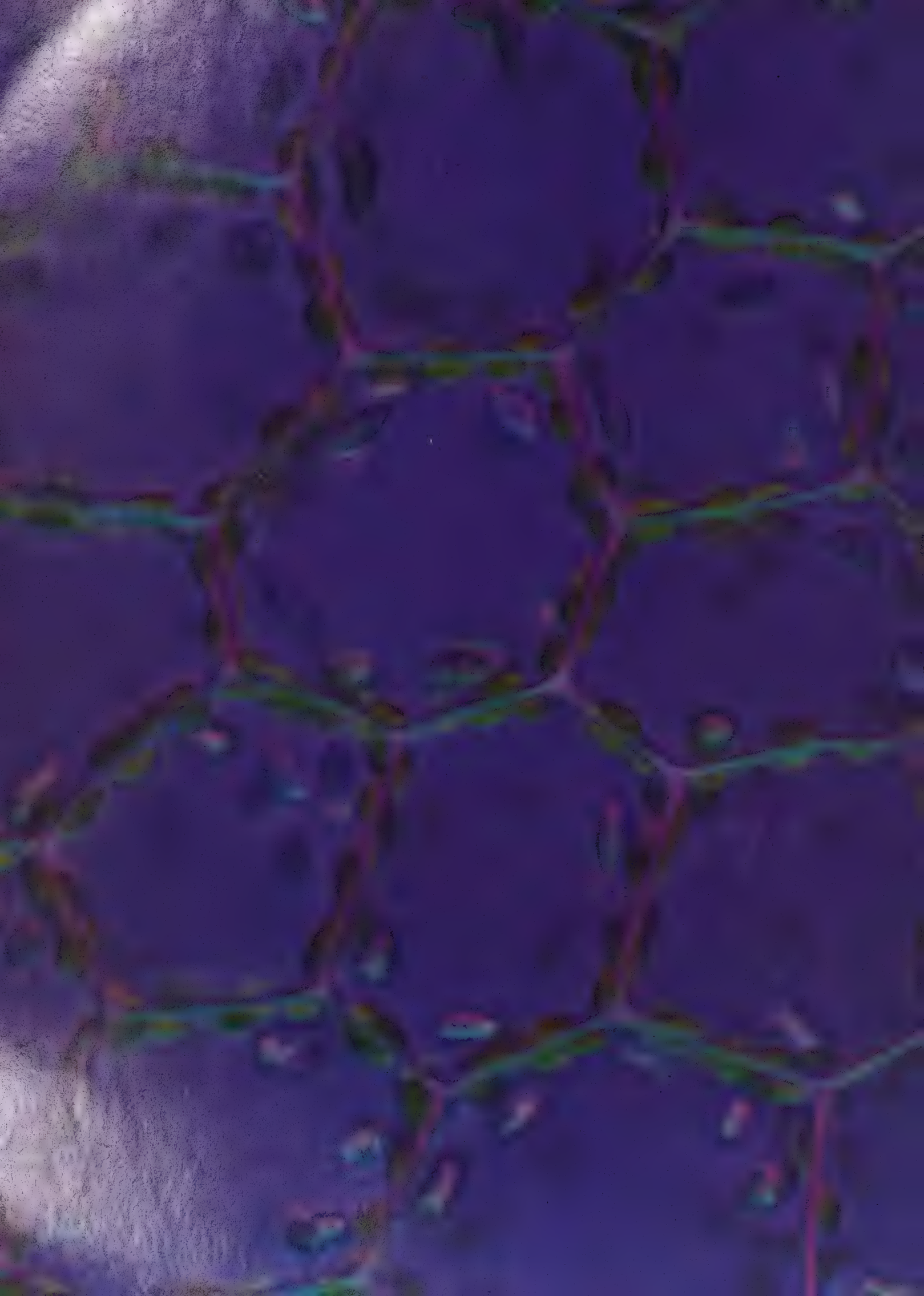
When the girls decide that the dough has enough water, Fateme kneels at the other side of the basin, turns up her sleeves, fastens her headscarf, says, "Bismillah o Raham o Rahim" (in the name of God, the merciful and compassionate), as her mother does when she starts this work, and pushes one knuckled fist into the dough, then the other, in and out, just as Goli does on her side. Their heads almost touch. When they have covered all the dough with their knuckles, they fold half of it over the other half and punch it down again. The dough sticks to their hands. Goli rubs her shoulder against an itchy spot on her cheek. Her scarf has slipped

Having at baking bread, Iran
Reinhold Loeffler

off her braids, and three red beads on a string in her left earlobe are bobbing up and down. The girls are breathing hard as they punch, fold, and punch in a perfect harmony of sound and movement, as if somebody is keeping time for them. Slowly, the dough is turning smooth, sticking to itself rather than to the hands and the basin. Goli decides it is done.

They wash their hands on the veranda with water from the kettle. Fateme leaves, flapping her arms to shake off the water. Back in the kitchen, Goli pats the dough a little before pushing the tray into a corner and covering it with heavy sacking. The dough will rest here overnight. Early tomorrow, Goli will roll the breads on her mother's heavy oak board and bake them on the griddle. It will take all morning, but perhaps her uncle's wife will help her.

Goli sits on the kitchen sill, elbows on her knees, chin in her hands, chewing gum. The sun is down. Goli has fed the chickens some bread dough and locked them up for the night. She has washed the tea things. The aluminum pot is at her side, ready to be used as a milk pail as soon as the cows are home. From the walnut tree in the yard, where a flock of sparrows gather every evening, comes loud twittering and chirping. Two boys at the other side of the courtyard shoot at the birds with rubber slings. There is a sharp, cracking sound, and the bird noise stops suddenly. Goli blows a pink bubble that sticks to her lips when it pops. Dusk is falling from the pale sky, is creeping out of corners. The coals in the fireplace on the porch glimmer faintly under the water kettle. Goli's aunt talks to her crying baby. From behind the wall a woman yells for Fateme. Goli blows another big bubble and looks down at it [illegible] her nose, cross-eyed. The bird noise has started again. A breeze touches [illegible] cheek. She is waiting for the cow; [illegible] her brothers; for the dinner she will serve on the rug; for the neighbor's lamps; for the stars above the roof—for the short night under her heavy cotton quilt. □



Oval-shaped chloroplasts, the tiny organs that power photosynthesis in all green plants, are visible here within a leaf of Canadian pondweed, magnified to 1,800 times life size. Almost all the oxygen in the atmosphere and oceans is a byproduct of photosynthesis.
Richard Kirby; Oxford Scientific Films

Oxygen, the Great Destroyer

Thanks to green plants, oxidation is the fate that awaits us all

by George Hendry

When life on Earth began, the atmosphere contained little or no oxygen. Since then, over the course of three billion years, the concentration of oxygen in the air has slowly risen. Today oxygen makes up more than 20 percent of the global atmosphere, and all living things, from bacteria to higher animals, fungi to plants, have had to adapt to it or shun it. To the most ancient organisms, the anaerobes, oxygen is a poison, and they seek refuge from it in deep muds. But the more highly evolved forms of life that now dominate the planet are completely oxygen dependent.

What makes oxygen so special is that it reacts readily with many other elements, a quality put to good use in the fundamental process of respiration. Almost all aerobic organisms use oxygen to "burn" the fuels that cells live on and to carry away the residues. When we breathe in, we absorb oxygen. When we breathe out, we release it in the form of carbon dioxide (a carbon atom bound to two atoms of oxygen) and water vapor (two hydrogen atoms bound to one of oxygen). Unlike oxygen, these waste gases are relatively unreactive; chemists would describe them as inert. The water ends up in the sea; the carbon dioxide is taken up by plants in photosynthesis or accumulates in the atmosphere as a "greenhouse" gas. The early forms of life, which lived in the absence of oxygen, used elements such as nitrogen or sulfur instead. Then, as now, these anaerobic organisms emitted some unpleasant-smelling waste gases, including ammonia and hydrogen sulfide (the stench of rotten eggs). In comparison, life in a world of oxygen may seem to us sweet and clean.

Unfortunately, living in a world of oxygen also exacts a price. Oxygen in its normal atmospheric form—the paired atoms known as O_2—is a powerful oxidant and can be destructive. Perhaps the simplest way to appreciate the element's double-edged nature is to look at how it affects some familiar substances. In the air or dissolved in water, oxygen attacks iron, causing it to rust and decay. Oxygen also tarnishes silver, sours milk, spoils wine, and turns butter rancid. The biggest problem faced by the food manufacturer is not so much the food-spoiling germs in the air—heat can destroy them—but oxygen, which rapidly combines with all foods. Oxygen in the air is so reactive that one careless match can destroy a forest.

In chemical terms, the element is so reactive because each atom lacks two electrons in its outermost "shell" and hunts for these two missing electrons by bonding with other elements. When it fails to pick up a full complement of electrons, however, oxygen becomes "activated" and is even more destructive than in its usual form. To take a simple example, one molecule of oxygen readily combines with four molecules of hydrogen to form two molecules of water, standing to gain four electrons in the process. If the electrons are not captured simultaneously and the oxygen molecule obtains only three, two, or one, then it relentlessly and spontaneously hunts out alternative sources of electrons, attacking its nearest neighboring molecule, which could be in an iron nail, a pound of butter, or proteins in human tissue.

Almost any natural chemical process that involves oxygen (fire, heat, volcanic eruptions, energy from sunlight, cell metabolism) can create activated oxygen. It forms when ozone (O_3—a three-atom form of oxygen) from industrial pollution reacts with water in a rainstorm. It forms when sunlight, particularly ultraviolet-B radiation, interacts with gases in the atmosphere, and this chemical reaction is probably one reason that early life forms avoided exposure to the element.

Within a living cell, some activated oxygen is inevitably produced during the chemical processes of respiration or photosynthesis, and it can attack cell tissue within microseconds. (The familiar yellowing of dying plants signals the last stage of an internal attack by activated oxygen.) Any such assault on cell proteins can cause the cell's enzyme-controlled reactions to fail. If activated oxygen gains access to the cell's DNA, it can rapidly maim the genes, interfering with their vital functions. Although the effects on proteins and DNA may not show themselves until after days or even weeks of assault, damage to the compartments within the cells is almost immediate. Lined with fatty membranes, cell compartments keep the orderly processes of life from slipping into chaotic chemical reactions. Cell membranes, just like butter, become hard and rancid when attacked by oxygen, and many scientists believe that such membrane oxidation lies at the heart of the aging process.

Scientists also believe that activated oxygen is the underlying agent of cell damage in many otherwise unrelated human diseases, from rheumatoid arthritis

David Muench

The rusting hulk of a car, right, testifies to the silent but ceaseless reactivity of oxygen in the air. Because oxygen readily attacks exposed iron, free oxygen did not begin to accumulate in the oceans or atmosphere until much of the available iron had been oxidized. Below: A conflagration in the Brazilian rain forest: the heat from one small match is enough to energize oxygen to react spontaneously through combustion.

H. Silvester; Black Star

to malaria to pollutant-induced lung damage. In essence, oxygen, once described as the elixir of life, wears us out.

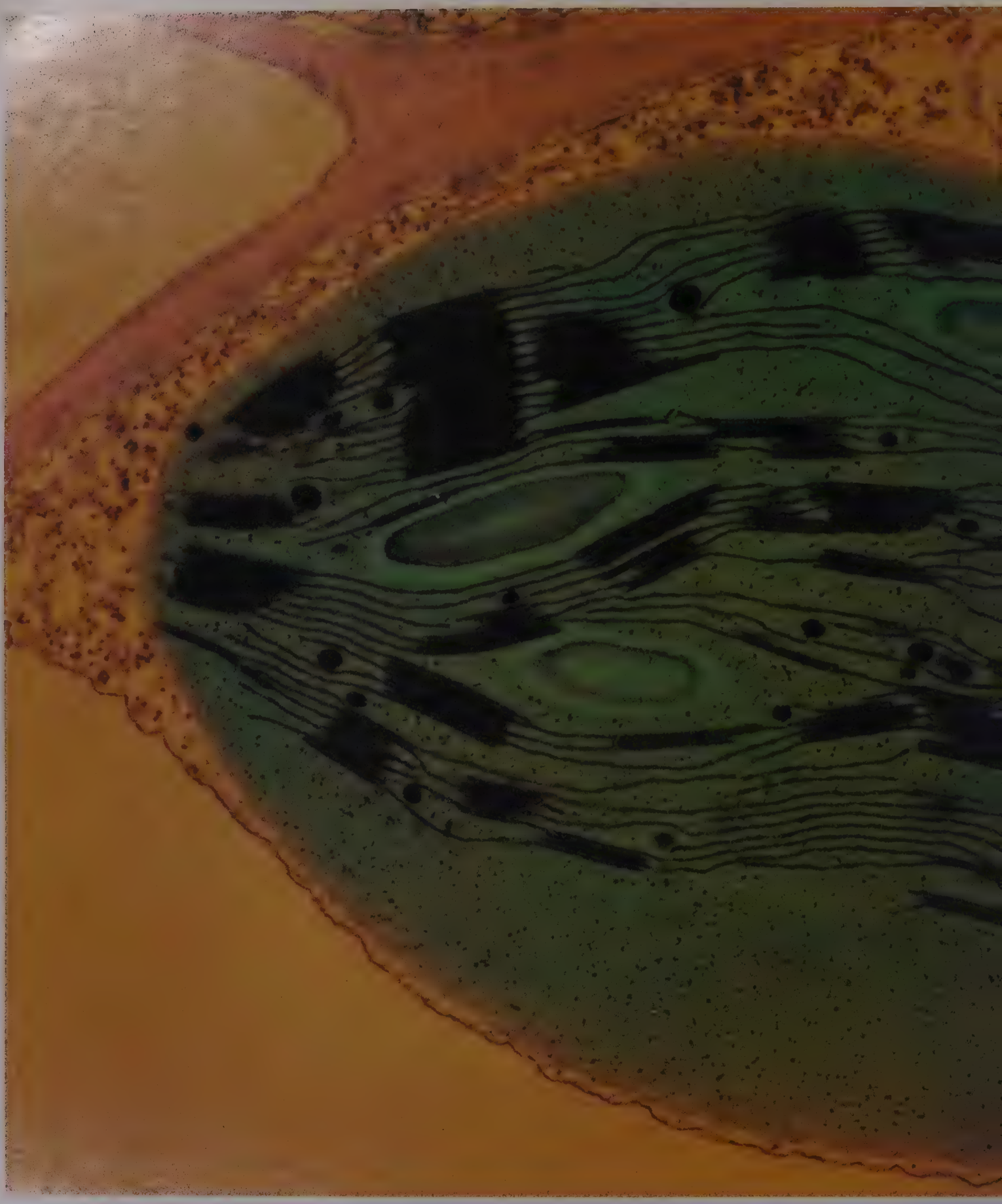
Were it not for plants, including seaweeds, there would probably be little or no oxygen in the atmosphere. Over millions of years, plants have released oxygen into the sea and air, enabling all the oxygen-respiring organisms to evolve. Plants, using the energy of sunlight in photosynthesis, convert carbon dioxide (our waste gas) into carbohydrates, including sugars. This process is, in effect, the opposite of animal respiration and insures that the carbon dioxide exhaled by animals and other organisms is rapidly recycled. Since the earth has a lot more plants than animals—99 percent of the earth's biomass is vegetation—plants take up carbon dioxide almost as fast as animals can release it. This is why the gas makes up such a small part, 0.03 percent, of the planet's atmosphere, even with the rise in CO_2 of the past fifty to a hundred years. Oxygen, on the other hand, has been released by plants over millions of years at rates much faster than can be consumed in animal respiration or by forest fires. Thus, today's plants are starving in a world of depleted carbon dioxide and drowning in one of excess oxygen. For 400 million years, plants have been polluting their own environment by producing oxygen. Other forms of life, including humans, have of course benefited from this pollution.

How do plants survive in the oxygen-rich world they have unleashed? From one perspective, that of productivity, they do relatively poorly. A plant like the soybean, if raised in an artificial atmosphere of just 5 percent oxygen, grows faster and produces more beans than it does in today's atmosphere of 22 percent oxygen, perhaps because its ancestors, the first land plants, evolved in an atmosphere of 5 percent oxygen or less. Atmospheric oxygen hinders plant growth because it interferes with the enzyme that fixes gaseous CO_2 into the organic acids that are in turn converted to sugars. This enzyme, ribulose bisphosphate carboxylase oxygenase, is i all plants and is, incidentally, the mo abundant protein on earth. At warm ten peratures, it reacts with oxygen instead c carbon dioxide, a largely wasteful proces that destroys many of the plant's hard-wo sugars. Studies of Kentucky's tobacc crops are an often-cited example of oxy

gen-induced loss of productivity—a considerably greater problem for plants now than it was 400 million years ago.

Plants, like animals, suffer from the effects of activated oxygen produced in the cell. The minute green organelles called chloroplasts are the cell's powerhouse of photosynthesis and work as an electrical circuit does: electrons released from the plant's water are directed through the photosynthetic apparatus, creating useable power. Just as happens in a test tube when electrons are passed through an atmosphere of oxygen, activated forms of oxygen are generated in the chloroplast. Plants are also exposed to activated oxygen when environmental stresses—from drought to acid rain to toxic metals in the water or soil—short circuit the photosynthetic apparatus of the cell.

Remarkably, even though increasing oxygen, depleted carbon dioxide, and a barrage of environmental pollutants have made their world more and more hostile,



plants continue to thrive. Of all organisms, they are by far the longest lived. Seeds may survive under cold and dry conditions for a hundred years or more. Trees commonly live even longer. One of the reasons for the longevity and hardiness of plant cells is that they contain a battery of defenses against the ravages of oxygen. The plant chemicals known to us as vitamins A, C, and E are important in controlling oxidative damage. In addition, chloroplast is richly endowed with special proteins—superoxide dismutase, ascorbate peroxidase, and glutathione peroxidase—that seek out and destroy activated oxygen.

The carotenoids—hydrocarbons, of which betacarotene is a widespread example—are forms of vitamin A closely associated with the green pigment chloro phyll. Carotenoids take the punch out o "singlet oxygen," a high-energy form o the element that bleaches chlorophyll th way that sunlight fades dyes in clothes o curtains. Because of carotenoids, gree leaves do not fade slowly over time. (In terestingly, mutant strains of corn occa sionally arise that are unable to mak

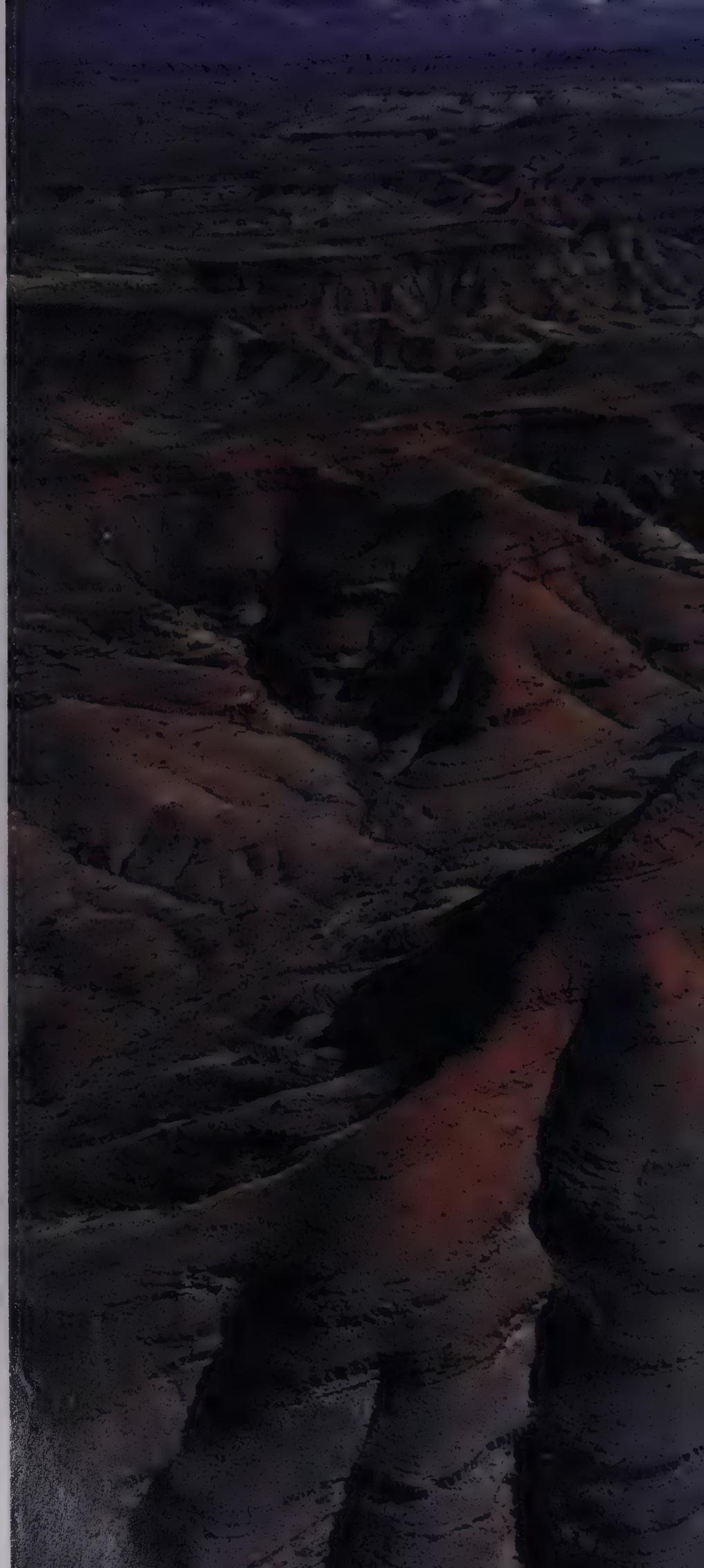
Within a chloroplast, seen here in a cross section magnified 45,000 times, photosynthesis inevitably generates activated, toxic forms of oxygen. If not scavenged by antioxidants such as vitamin E or C, which are made in all green plants, activated oxygen will rapidly destroy the green chlorophyll and surrounding structures.
Biophoto Assoc./Science Source; Photo Researchers, Inc.

carotenoids. The seedlings of such mutants can only be kept alive under anaerobic conditions, and any oxygen released by the plant must be removed as soon as it is produced.)

Plants make large quantities of vitamin E, a fat-soluble chemical that protects the fatty components of cell membranes. Also associated with the chlorophyll molecule, vitamin E protects the plant from highly toxic forms of oxygen called oxygen radicals. These damaging molecules, formed by the inevitable wear and tear of the electrical circuits in cells, attack and punch holes in the fatty walls of cell compartments. Vitamin E deposits sit strategically across the membranes and mop up any stray radicals. Ascorbic acid, or vitamin C, is a water-soluble antioxidant that protects proteins outside the membrane and probably on the membrane surface. It also repairs "used" vitamin E.

The most evolutionarily advanced animals, including humans, have lost the ability to synthesize these antioxidant vitamins internally and depend on foods to supply them wholesale. Plant-eating animals, from caterpillars to cows, have direct access to a rich supply of vitamins A, C, and E and, provided their food supply does not run out, are reasonably well protected from oxygen attack. Animals that secure much or all of their food from eating other animals have only indirect access to plant antioxidants. Carnivores such as polar bears, for instance, don't have access to fruits and vegetables. They get their vitamins by consuming the seals that eat the fish that eat the protozoans that, in turn, *do* eat plants—the algae. But all animals must procure vitamins in some form. Most cannot survive without pro-vitamin A, a carotenoid, in their diet—not only because it helps make the light-absorbing pigments of vision but also because it scavenges activated oxygen. In humans, deficiencies in vitamins A, C, and E have long been known to cause such diverse disorders as night blindness, scurvy, infertility, and retarded growth. In some cases, specific plants were prescribed for deficiency diseases well before the identity of the missing compound was known to science. In Britain and Scandinavia, for instance, the seashore plant called scurvy grass, exceptionally rich in vitamin C, was used for its medicinal, scurvy-preventing properties until (in the British navy, at least) it was replaced by limes.

But whether plant or meat eating, animals under stress, from disease or cold or lack of water, increase their demand for vitamins—a need that can be met only by increasing intake of specific foods, not al-



The [illegible] layers of Australia's [illegible] Basin represent thousands of years of sedimentation in an ancient sea. Among the oldest red iron oxide deposits on the planet, they were formed in waters rich in oxygen and signal the rapid expansion of photosynthesis by microscopic algae 2.5 billion years ago.
Reg Morrison; Auscape International

ways easy or possible. As many farmers know too well, demand for extra vitamins by stressed animals often occurs when the raw source, plants, is not available.

In terms of antioxidant defenses, plants are more self-reliant than animals. We, at the University of Sheffield, as well as other researchers, have shown that plants under stress can rapidly turn on their vitamin-making processes. Just how rapidly can be seen in plants exposed to drought. When water shortage starts to bite, the first line of defense appears to be vitamin C, usually present in some excess. As the vitamin C is used up during the first day or two of drought, the plant opens up a second line of defense. Some plants, particularly those growing in nitrogen-rich fertile soils, produce considerable quantities of another water-soluble antioxidant, glutathione. Others take their defenses back into the fatty membranes and rapidly lay down large amounts of vitamin E. Using these three antioxidants, the plant can protect the vital functions of the chloroplast for at least several days. If the water shortage continues, the plant begins to divert its resources into making a number of elaborate, metal-containing protective proteins. One, superoxide dismutase, catalyzes the rapid destruction of one kind of oxygen radical and seems to be able to do so for many days. The plant cannot, of course, survive a drought indefinitely. But the function of the antioxidants and protective enzymes is to see plants through a short-term crisis.

The humble plant, faced with both natural and unnatural environmental fluctuations—from scorching days to freezing nights, from floods to droughts, from herbicides to industrial pollutants—takes a battering. The key to its resilience may be the ability to stop oxygen in its destructive tracks. In this way, a plant is far better adapted to living in a world of oxygen than almost any other organism. □

Notharctus, *an extinct North American primate, is depicted leaping through hardwood forests 50 million years ago.*
© 1991 Jay H. Matternes for AMNH

Alas, Poor *Notharctus*

An ancient lemuroid skull tells of life—and sudden death—in Wyoming's forests

by John P. Alexander

On June 12, 1988, paleontologists Eugene Gaffney and Frank Ippolito of the American Museum were searching for fossil turtles in the layered badlands of the Bridger Basin, in the southwest corner of Wyoming. When they spotted some fragments of an unknown fossil protruding from a rock wall, Ippolito dislodged a heavy block and began removing peripheral pieces to lighten it. A chance hammer blow split the stone in half, revealing the well-preserved skull and skeleton of a small mammal. The team wrapped the specimen in a jacket of plaster and burlap and later drove it to New York, along with their prize catch of Eocene turtles.

Several members of the staff of the Department of Vertebrate Paleontology were on hand when the fossil-bearing rocks arrived at the Museum's laboratory. I remarked that an exposed elbow in the mammal-bearing block looked primatelike. Malcolm McKenna, Frick Curator of Paleontology and a world authority on the evolution of early mammals, gave the specimen a cursory inspection. He thought that several broken cheek teeth, which had been exposed in profile, resembled *Hyopsodus,* a small, vaguely hyraxlike creature common in Bridger Basin deposits. As manager of the Museum's fossil mammal collection, I was expected to catalog the specimen and deposit it with the condylarths, a group of primitive relatives of the hoofed mammals.

Museum collections are often better places to make extraordinary discoveries than the field. Had I put it away immediately, this specimen might have resided unrecognized among our *Hyopsodus* collection for years. Instead, I set the thing on my desk and stared at it on and off for several weeks. One quiet Saturday afternoon, I took the block into the empty lab and began working with a miniature pneumatic hammer to release the smooth brown bone from the grip of the ancient rock. Within five minutes, I had exposed a postorbital bar on the skull. The sight jolted me. Such a bar, formed by extensions of the frontal and maxillary bones, creates a bony ring around the eyeball. Most mammals lack this feature; modern primates are among the few groups that have it. After an hour I knew that I had one of the half dozen most complete primate skulls that had ever been found in North America. At that moment McKenna happened to walk into the lab. With a grin he remarked that it was the strangest *Hyopsodus* skull he had ever seen.

At first I thought the specimen was *Smilodectes,* a kind of early prosimian best known from skulls in the Smithsonian Institution collection. In an important study published in 1958, paleontologist C. L. Gazin had described examples of the ancient primate *Smilodectes* and the related genus *Notharctus.* But whereas *Notharctus* had for decades been reconstructed as a fox-faced little primate similar to today's ring-tailed lemur, Gazin's reconstruction of *Smilodectes* suggested that it was a more advanced form. Nonetheless, when I cleaned my new "*Smilodectes*" I noticed that its dentition was that of a *Notharctus,* examples of which had been in our collection for years.

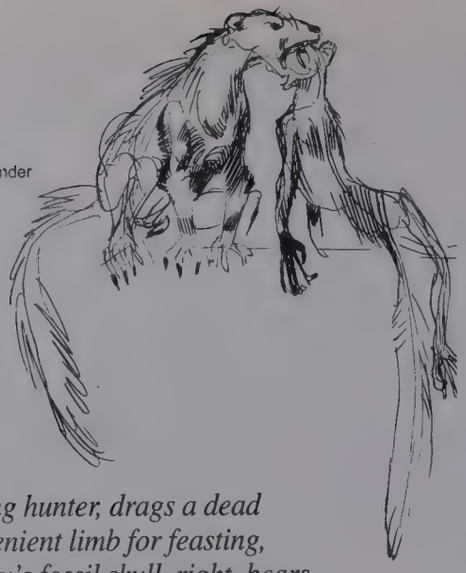
This clue led me to realize that the new skull could revise our understanding of both creatures. It was the first complete and uncrushed representative of an early notharctid prosimian. For the first time we could see what the heads of these animals looked like: the small, broad face with fully binocular vision was close to what one might expect of the common ancestor of monkeys and apes. Neither the long-muzzled, narrow-faced image of *Notharctus,* reconstructed by William King Gregory in the 1920s, nor the arch-nosed, broad-faced reconstruction of *Smilodectes gracilis* derived from Gazin's later work could be accurate.

Guided by the anatomy of related living prosimians, such as the sifaka of Madagascar, I anticipated new details with each bit of rock removed. The large canine teeth and the sagittal crest, or ridge of bone, on the top of the head (for attachment of powerful jaw muscles) were secondary sex characteristics commonly seen in anthropoids but not in modern lemurs, and they indicated that I was dealing with a male.

As it emerged from its rock matrix, the skull presented another surprise. Just above and behind the left eye I encountered a hole, about as wide as a pencil, that wasn't supposed to be there. Next, I found a hollow depression punched into the bone behind the other eye and a small nick in the cheekbone. Assuming the role of a coroner 50 million years after the fact, I realized that I had a "notharcticide" on my hands, a conclusion further supported by evidence of a puncture wound to the first neck vertebra and the splitting of the third. I named the little victim Butch Casualty in honor of his Wyoming origin and his cruel demise. Somewhere among the long-vanished treetops of Wyoming's Eocene forests, Butch's neck had been broken by a bite from behind, and the right side of his face crunched in the jaws of a predator.

Notharctus shared its primeval forest with a rogues' gallery of archaic predators, ranging in body mass from the jaguar-sized *Patriofelis* to the weasel-sized *Thinocyon.* Whichever hunter was respon-

John P. Alexander



Peter Goldberg

Vulpavus, *a tree-living hunter, drags a dead* Notharctus *to a convenient limb for feasting, above. Butch Casualty's fossil skull, right, bears a circular puncture on its cheek, presumably made by a predator's fangs.*

sible had possessed upper canines that were oblately triangular in cross section and spaced about half an inch apart: a mammal about the size of a pine marten. I had to exonerate those suspects that were the wrong size or whose canines were the wrong shape. *Machaeroides,* for instance, was a saber-toothed predator with a mink-like body and fangs that were too long and lozenge-shaped in cross section. I ruled out each animal in the lineup except a creature called *Vulpavus,* an arboreal predator with robust limbs, which enabled it to shinny up a tree like a wolverine. *Vulpavus* had flat feet tipped with large, bladelike claws, and its anatomy is consistent with that of a tree-dwelling predator. Today, the only carnivore like it is the binturong, a wiry-haired relative of the mongoose from the forests of Southeast Asia.

My excitement in discovering Butch prompted me to spend every spare moment during the next year reexamining the American Museum's large Eocene mammal collection. Drawer by drawer, I searched for additional examples of *Notharctus* that may have escaped proper identification. Among my discoveries was a second skeleton of *Notharctus* that, according to our records, had been collected by Paul C. Miller in 1922. It had been misidentified as a carnivore, and later its head and body had been inadvertently separated. I reunited the skeleton and named it Harry in honor of the corpse that keeps disappearing and rematerializing in Alfred Hitchcock's film *The Trouble with Harry.* Harry possesses the best-preserved shoulders and hips of any example of the genus. Together, Butch and Harry have filled in many of the missing pieces of an old puzzle that had intrigued some of the greatest names in vertebrate paleontology.

For decades *Notharctus* had been characterized as the "best-known" early primate, yet we still knew little about the animal. Many details of its skull and skeleton had been inferred from the better-known prosimian primates of Europe, the adapids, leading to the erroneous conclusion that North American forms were more primitive than their European counterparts. In fact, *Notharctus* had a much smaller muzzle than either extinct adapids or many living lemurs and may have independently evolved a few features of anthropoids, such as the reduced lachrymal bone of the face. I tend to believe that in some ways *Notharctus* more closely resembles the ancestral stock that produced the monkeys and apes than the line that led to the Malagasy lemurs and sifakas.

Since Butch's discovery in 1988,

Lemurs, Then and Now

Today's Malagasy lemurs may be descended from European adapids, an extinct early primate group that shared common ancestors with the North American notharctids back in the early Eocene. But by the later Eocene, when *Notharctus* was leaping through the trees of ancient Wyoming, the land route between Europe and North America had been broken, and the two lineages had already gone their separate ways. Although *Notharctus* and its North American relatives can be characterized as lemurlike, they were not true lemurs. The lemurs living on Madagascar today, including related indrids such as the sifaka and the enigmatic aye-aye, represent a separate line that has diversified into a great number of ecological niches. However, the sifaka *Propithecus verreauxi* is the living primate most analogous to notharctids and can give us a vivid idea of what these ancient creatures may have been like.

Active in the daytime, modern sifakas feed on fruits and foliage and occasionally venture down to the forest floor. On the ground, sifakas have a tendency to rise up on their hind legs and amble about bipedally, making short sideways leaps—actions *Notharctus* may also have performed. Most species of lemurs travel on all fours, have flat nails on their hands, and possess a specialized "toilet" claw on their hind feet, with which they groom their fur. Like monkeys, most lemurs have binocular vision, reduced reliance on the sense of smell, and grasping hands.

A caprice of biogeography allowed prosimians to reach Madagascar and live unmolested by most predators for tens of millions of years. Beginning a few thousand years ago, human settlers hunted thirteen species of native lemurs to extinction. The largest of them, the ape-sized *Megaladapis,* was finally exterminated only a few centuries ago.

Today's remaining Malagasy prosimians are also threatened with imminent extinction because of relentless hunting and deforestation by humans. Unless significant efforts are made toward habitat preservation, it appears that these creatures, which are so much like the early ancestors of all anthropoids, may soon disappear at the hands of the world's most recently evolved primate.

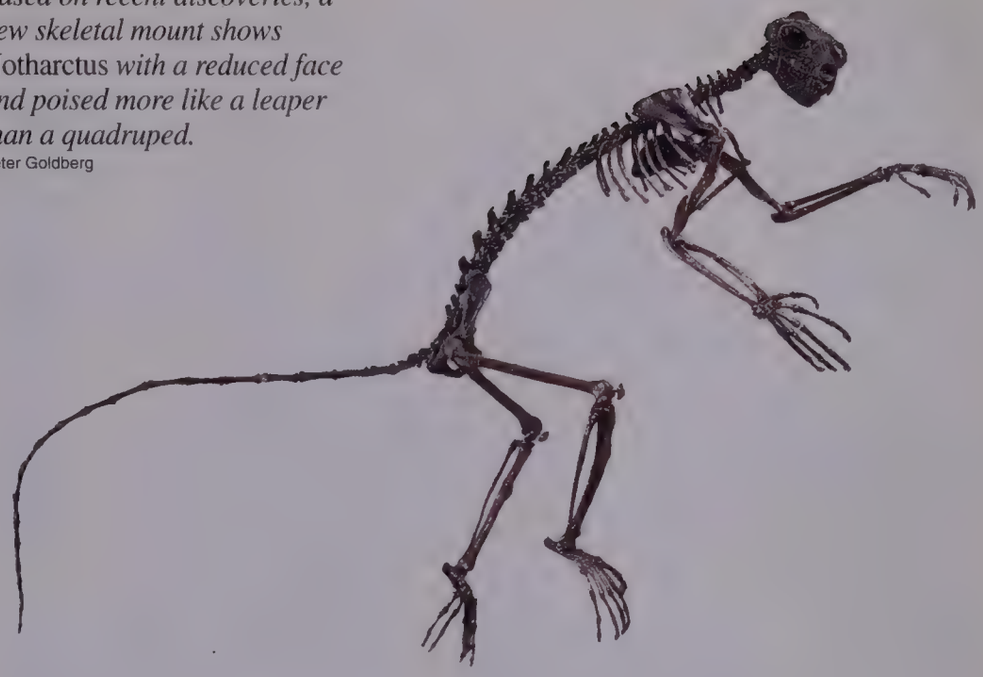
thoughts about this little *Notharctus* dominated my waking hours. I hoped to find its right hand, a part of the skeleton that was missing. When I had the opportunity to join a University of Colorado field team working at Bitter Creek, east of the Bridger Basin, in 1991, I jumped at the chance to spend a day trying to relocate the site of Butch's discovery. Three colleagues and I managed to find the spot, but unfortunately, the only fossils evident there were a few toe bones from a rhino-like beast called *Hyrachyus.*

July 11, 1991, was a special day: astronomers from Hawaii to Baja California were busy observing one of the premier total solar eclipses of the century. Recalling admonitions never to look directly at an eclipse, I projected a reversed image of the sun onto the ground through my binoculars. One of my colleagues, Robert Anemone of the State University of New York at Geneseo, glanced at his watch and reminded me that our available search time, as well as the eclipse, was waning.

Returning my attention to fossil hunting, I picked up the *Hyrachyus* toe bones, imagining the thud of hoofs and the rustling of fronds as this boar-sized rhino cousin galloped through palmetto glades. I scanned the high desert before me and reminded myself that this land was once watered by a chain of broad blue lakes ringed by lush forests comparable to today's Florida Gulf Coast. Palms, cypresses, fig trees, and willows grew in the basins. Hardwoods, such as elms, oaks, and beeches, yielded to conifers at higher elevations, where dense forests once continued up to 6,000 feet. Some of the best evidence of such Eocene forests, which blanketed much of the Northern Hemisphere, have been found on Axel Heiberg Island above the Arctic Circle in Canada's far north, where actual wood and leaves have been preserved.

As the Western Rockies were being thrust upward to ever greater heights, volcanoes in what is now Yellowstone National Park frequently belched plumes of ash that intermittently blanketed the area. Rainstorms washed these volcanic cinders down stream beds and into aggrading basins, forming sedimentary strata that interred the remains of many forest animals. Millions of years later, erosion and weather exposed them to the surface again, like slices of a layer cake. Today these Wyoming badlands contain some of the best-preserved early mammal fossils.

We had to quit early to rejoin our colleagues at the Bitter Creek camp ninety miles away, but we decided to allow ourselves one more hour of prospecting for fossils. About twenty minutes later, I noticed bits of bone at the surface of a clay stone bed. I quickly fitted the fragments together and realized that I was holding a whole jaw of *Notharctus tenebrosus,* including the mandibular symphysis, which joins the two halves together—a superior specimen. The large canine socket indicated it was probably the jaw of a male. I called to my colleagues, who converged on my location like ants at a picnic.



Based on recent discoveries, a new skeletal mount shows Notharctus *with a reduced face and poised more like a leaper than a quadruped.*
Peter Goldberg

On our hands and knees, we scrutinized the ground until Linda Levitch, of the University of Pittsburgh, drew my attention to a tiny bone exposed on the white cliff face about six feet from where we found the first mandible. When I told her that it was the phalanx, or finger bone, of a *Notharctus,* Bob Anemone guffawed and accused me of seeing a *Notharctus* under every bush. In fact, I had become so familiar with the anatomy of *Notharctus* that if one had been under a bush, I'd have been likely to find it. Less than an inch behind this phalanx we found another complete jaw and an associated partial skeleton of a female *Notharctus* that had not seen the light of day for almost 50 million years.

Only two of the ninety-eight *Notharctus* jaws collected by the American Museum during the past century are as complete as the pair we found that afternoon of the eclipse. I nicknamed the new specimens Cosmo and Cosema in honor of the cosmic circumstances of their discovery and the astronomical odds against it.

On our way back down the highway, we toasted our good fortune with ice cream cones at the Little America Truckstop. The first paleontologists to pass through the Bridger Basin more than a hundred years ago would have been lucky to slake their thirst out of a wet horseshoe print. Much has been written about the hunt for early primates in such far-off locales as the Great Rift of Africa or the "dragon bone" caves of China, but we had the pleasure of finding distant relatives of humankind just off Wyoming's Interstate 80, which parallels the old Union Pacific right of way. Our site has turned out to be one of the richest repositories of fossil primates in North America.

Eocene sediments of western Europe contain a splendid fossil record of adapids, but the exact relationship between them and their North American cousins is still obscure. During the early part of that period, animals were still able to travel between the two land masses across the then temperate Arctic. The fossil record indicates that a few million years later, connections between the populations were severed. Continental drift eventually widened the distance between Europe and North America, and prosimian groups in the Old and New Worlds seem to have evolved separately.

World temperatures began to cool in the Oligocene, and the vast, continuous woodlands gave way to many areas of grasslands, or savannas. In the higher latitudes of North America, primates were steadily excluded from their former extensive ranges. Some prosimians may have survived the Oligocene in Mexico and Central America until the advent of New World monkeys, which seem to have taken over their arboreal niches. The last prosimians known from North America

The Changing Image of *Notharctus*

This classic restoration from the 1920s depicts Notharctus *as a fox-faced, quadrupedal lemur.*
Francis L. Jaques; AMNH

In 1869, shortly after the Union Pacific Railway linked the continent from coast to coast, museum collectors from the East headed for the fossil-rich western badlands, where the earth was yielding hundreds of previously unknown species. Field teams on muleback, sent by rival pioneer paleontologists Edward Drinker Cope and Othniel C. Marsh, scoured the Bridger Basin and shipped tons of fossils back to Boston and New Haven by rail. An enigmatic little jaw collected from Cottonwood Creek was part of the treasure trove of ancient mammal remains.

In 1870 the relic was described by Joseph Leidy, of Philadelphia's Academy of Natural Sciences, who named it *Notharctus tenebrosus,* or "dark spurious bear," because he thought it might be related to raccoons. Later, he decided that the jaw had more in common with early ungulates.

In 1902, Henry Fairfield Osborn, the director of the American Museum of Natural History, was the first to recognize the fragment as possibly the oldest example of a primate, but its relationship to lemurs, monkeys, or apes has been a matter of debate ever since. When Osborn sent a field team to retrieve more Eocene mammalian fossils from Wyoming, he alerted them to search for more complete specimens of *Notharctus*. The first skull was found on the last day of June 1903 by L. S. Quackenbush in the company of Walter Granger, who wrote "?Notharctus" in his journal. Granger also found parts of two skeletons, each about 20 percent complete.

A description of that badly crushed skull formed the basis of a hefty tome published in 1920 by William King Gregory of the American Museum, which became the definitive description of the genus for decades. Following Gregory, Museum preparator Alfred Thomson assembled a mounted skeleton of *Notharctus* that was about 20 percent fossil and 80 percent plaster. It became a classic exhibit, on display continuously for seventy years, during which its picture appeared in hundreds of publications, from scientific journals to children's books.

Our present image of *Notharctus,* relying heavily on the specimens known as Butch Casualty and Harry, shows the animal with a shallower face than had been thought, which is consistent with a leaper rather than a quadruped. John Alexander's new skeletal mount and Jay Matternes's mural depicting *Notharctus* in life will be displayed in the American Museum's Hall of Human Biology and Evolution, scheduled to open in the spring of 1993.

A tree-dwelling leaper and climber, Verreaux's sifaka of Madagascar is the closest living analogue of Notharctus. *On rare excursions to the ground, it may resort to an awkward form of bipedal locomotion.*
Frans Lanting; Minden Pictures

date back to the early Oligocene (27 to 34 million years ago) and were found in southern California and the Big Bend area of Texas. After that time, the fossil record of prosimians in Europe also dwindles away. Remains of lemur cousins, such as lorises and bush babies, from the later Tertiary have occasionally been found in Asia and Africa, where these animals dwell today, but the only post-Oligocene fossil record of lemurlike creatures comes from comparatively recent deposits on the island of Madagascar, the last stronghold of living prosimians.

Notharctus was a forest dweller with long and powerful hind legs for leaping from tree to tree, like modern sifakas from Madagascar, which can clear twenty-foot gaps with ease. Most modern lemurs tend to have long feet with grasping big toes, but *Notharctus* also had long hands with elongated fingers for clinging to trunks and branches. Like today's Malagasy lemurs, *Notharctus* had a long tail that probably helped the animal balance when it performed its arboreal acrobatics.

What is most impressive about *Notharctus* is that it demonstrates that a relatively advanced state of primate evolution had been achieved by the first half of the Eocene, 50 million years ago. Its grasping hands and feet, with nails instead of claws, were already very much like those of later anthropoid primates. This basic primate adaptation for manipulating food and carrying it to the mouth eliminated reliance on an elongated muzzle. The animal's eyes were set far enough forward to produce stereoscopic vision, or depth perception—no small advantage in the maze of the treetops. Such an overall gain in awareness of the environment may have set the stage for the further expansion of primate brains that occurred in the Oligocene. By studying today's lemurs, we are able to gain some idea of what the lives of our ancient relatives such as *Notharctus* were like, and thus to picture more accurately the early stages of our own evolution. □

The Artist Who Saw Through Time

by Robert McCracken Peck

"As a small boy," wrote Charles R. Knight (1874–1953), "all sorts of living things intrigued my youthful imagination and inspired my endeavors to place on paper somehow and in some way a representation of the animal forms to which I was so devoted. There was no special art consciousness about these attempts, merely a primitive urge to depict what I saw before me, much in the manner of the ancient cave man who loved to grave and color upon the walls of some remote cavern the shapes, tints, and actions of the various wild beasts that existed in his immediate neighborhood."

A special exhibition, **The Prehistoric Mammals of Charles R. Knight**, will be on display in the American Museum of Natural History's Akeley Gallery through the end of October 1992.

Knight's urge to depict his surroundings led him, in time, to a career as the country's most influential painter of the prehistoric world, making him the man many credit with bringing dinosaurs—and a host of other long-extinct creatures—out of the attic and into the public eye. While his own Brooklyn neighborhood was decidedly lacking in wild animals, New York City's Central Park Zoo and the American Museum of Natural History, "at that time only a single red brick building which rose from a pile of broken rods in the center of Manhattan Square," offered more than enough exotic creatures to satisfy the imagination of a lonely but creative child.

With special visiting privileges arranged by J. P. Morgan, for whom Knight's father served as a private secretary, the young boy first began coming to the Museum before the age of five. As he recalled later in life, "The long tiled halls filled to overflowing with glassy-eyed birds and animals, each on its own mahogany base, fascinated me, and we had them all to ourselves, as the Museum was not then open to the public on Sundays. I presume the taxidermy was pretty bad, and many of the specimens were old, cracked, and faded—but to me they were a wonderful show and I vastly enjoyed looking at them. I particularly remember one striking group of an Arab camel rider being attacked by a lion...only an artist could have done it. The man of course was wax, but his expression as he sat astride the camel's neck to escape the claws of the big cat was well worth seeing.... All these little excursions into the vast realms of animal life must have stimulated in my youthful mind an already intense desire to draw or otherwise portray the forms and colors of the creatures that I now realized lived in the world about me. Gradually I began to draw, at first from copy books, but later from living animals."

At the age of fifteen, Knight began taking classes at the Metropolitan Art School in the basement of the Metropolitan Museum of Art. The next year, he added classes at the Art Students League. After his father's death in 1892, Knight moved into Manhattan and found the American Museum's collections not only stimulating but also central to his education: "I loved to hang about the mussy little wooden shop that in those days passed for a taxidermist's studio, there to feast my eyes upon what seemed to my prejudiced gaze a galaxy of treasures in the form of mounted animals, birds, skins of various kinds, and plaster casts of dead specimens. Even the walls were decorated with heads and horns, trophies of the chase from all quarters of the globe. To anyone not keenly set upon such things, this bizarre conglomeration would have been truly distasteful, but to me it proved a veritable mine of knowledge and instruction."

By this time, in the early 1890s, the Museum had grown, with a new south wing added to the red brick building in the middle of Manhattan Square. Evidently, a special arrangement existed between the Museum and the Central Park Zoo, because Knight wrote in his unpublished memoirs: "We used to wait eagerly for specimens to arrive from the old Central Park Zoo, usually in pretty poor condition.... Nevertheless, we got busy on them right away. I drew close-ups of noses, eyes, paws, ears, and the boys made plaster casts before and after skinning. Then we'd study the muscles and the bony structure, and again I'd draw assiduously from the defunct and sometimes smelly cadavers. It was a real anatomy course, as far as it went—a dead tiger, a lion, a queerly formed kangaroo, or a much disheveled macaw or pelican, they all came one after another, under our careful scrutiny, and we learned a lot about their forms and proportion.... I very soon found that when I again drew from living animals, my bone and muscle studies had given me a far deeper insight into their general construction than I had formerly possessed, and that I was able better to interpret the position and flow of the muscles as the animals moved about in their cages."

In 1893, between art classes and regular visits to the Museum and the Central Park Zoo, Knight began to seek free-lance work in illustration. In order to devote more time to his studies he had given up a job painting crèche animals for a company that produced stained-glass windows for churches. But now, driven by a need for funds and a desire to prove his worth in the marketplace, he began to show his portfolio of animal drawings to New York publishing houses and magazines.

In 1890, the American Museum of Natural History, below, was in the midst of expanding its quarters. Bottom: Jules Verreaux's Arab Courier Attacked by Lions *was displayed at the 1869 Paris Exposition and later transferred to the Museum, where Knight saw it as a five-year-old boy.*
AMNH

Courtesy of the Carnegie Museum of Natural History, Pittsburgh

At first he was received rather coolly, but he proved to be persistent, "going back again and again to see editors, sub-editors, and just office boys. Finally, and at a lucky day for me, I went to the American Book Company a second time and there met an assistant editor. This handsome young man, with deep black eyes and curling hair, received me most graciously, listened to what I had to say, and then promptly offered me several small illustrations to do for children's readers. I was delighted. Here at last was an opening.... He offered me $25 apiece for the pictures, which was very good pay, as they each took me less than a week to do. I trod on air all the way to Harlem [where Knight was living at the time]. It was truly a windfall, as my friends were making from $2 to $12 per week, working hard all day in some downtown office, and here I was an independent young man, just beginning, getting $25 at least every week for a few days' work and at home and in my own time. It was wonderful and my stock rose tremendously in the estimation of my friends.... It gave me a tremendous mental stimulus, this sort of work, and it was just what I had always wanted to do without knowing just how to get at it.... I was now an illustrator...and embarking on what was really to be my life career."

While still in his early twenties, Knight began to free-lance for *McClure's,* a popular magazine notable for its scientific articles, its portraits of people, and its fresh and lively fiction. Here he met and worked with an impressive array of talented writers, including Sir Arthur Conan Doyle and Rudyard Kipling.

With each published illustration, Knight's reputation as an artist grew, and as it did, his friends at the Museum began to treat him more as a professional colleague than a student. One day John Row-

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For a mural depicting Cro-Magnon painters, right, Knight chose the mammoth scene from the limestone cave of Font-de-Gaume in Dordogne, France. Below: A photograph of Knight taken in 1894, when the artist was twenty.

Photographs courtesy of AMNH

ley, the Museum's head taxidermist, asked Knight if he would like to put his anatomical knowledge and drawing ability to work reconstructing a fossil animal. Knight was intrigued by the challenge. "My modest reply was that I would try, and what was the beast he had in mind?" he recalled. "It proved to be a curious piglike animal—*Elotherium,* with special and peculiar characters which set it off more or less in a class by itself. I completed the drawing satisfactorily in black-and-white watercolor, and it still hangs in the Museum by the specimen. The date was 1894. Thus, without realizing it, I had stumbled on a kind of work which was to occupy me much of my time for the next forty years or more."

Although earlier artists had tried to depict creatures of the prehistoric world, none had started with Knight's combination of anatomical knowledge and artistic ability. In the early nineteenth century, prehistoric fossils were rarely found in natural history museums. Those that were were not displayed with much imagination until 1868, when Philadelphia's Academy of Natural Sciences employed the British sculptor Benjamin Waterhouse Hawkins to reconstruct a skeleton of *Hadrosaurus foulki.* The effect was dramatic, and attendance skyrocketed as thousands flocked to view the bony behemoth. Encouraged by the public's response in Philadelphia, other museums rushed to secure and display prehistoric fossils of their own. At the time Knight began working at the American Museum, the institution was just beginning to amass a collection of fossil skeletons. By adding flesh and fur to these bones, Knight seemed to breathe life into the subjects of his paintings. Inadvertently, he had discovered—and filled—a niche in which he could combine his talents in science and art.

The person who most fully appreciated the educational and commercial potential of Knight's talent was Henry Fairfield Osborn, the head of the Museum's paleontology department (and later, president of the Museum). "Professor Osborn was young, well trained, and enthusiastic," recalled Knight, "and he wished to make a fine showing of things prehistoric for his newly acquired department. Above all, he was something of a naturalist and an artist at heart, and he had a great appreciation of all things living and beautiful. Also, he saw the necessity for embarking on some plan or method of installation that would interest the intelligent laymen in his fast growing gallery of fossil creatures. We saw eye to eye from the first in these matters and realized the possibilities ahead of

us and set to work with a will to make our schemes a success."

When Osborn arrived at the Museum to establish its paleontology department in 1891, Yale and the Academy of Natural Sciences dominated the still-nascent science of paleontology in America. Under Osborn's dynamic leadership, the American Museum's collections began to grow in size and importance. Knight could not have been on hand at a better time.

"While the laboratories hummed with the sound of drills, scrapers, and mallets wielded by the skillful hands of numerous excellent preparators, specimens of all sorts, shapes, and sizes poured in from the field expeditions, several of which were out most of the summer, and big and little bones were unearthed from their long rest beneath the soil of some western state and later assembled and placed on exhibition. It was an inspiring time for all of us—we were young, strong, and energetic, filled with enthusiasm and determined to make our halls the finest in the world. In my modest role as artist, I modeled and painted the various extraordinary creatures as they were set up, and my productions were placed close by the mounted specimens as a guide to the imagination of the public."

Under Osborn's direction (and with financial support from J. P. Morgan), Knight went on to paint thirteen immense murals of prehistoric life for the Museum. Seven of the murals are undergoing restoration for the new Hall of Vertebrate Paleontology, opening in the fall of 1993. In addition, Knight's mural of Cro-Magnon cave painters is being restored for the opening of the Hall of Human Biology and Evolution in May 1993, giving support to Osborn's bold prediction that Knight's work at the Museum would "endure for all time." Although subsequent discoveries have changed our knowledge about some of Knight's subjects, the power of his paintings still grips us today. During his long and prolific career (he was still painting at the time of his death in 1953), Knight painted murals of prehistoric life for museums in Washington, D.C., Pittsburgh, Chicago, Los Angeles, and Scranton, Pennsylvania, but it was the American Museum that—from the age of five—he always considered home.

Naturalist and historian Robert McCracken Peck is a Fellow of the Academy of Natural Sciences of Philadelphia. He is the author of A Celebration of Birds: The Life and Art of Louis Agassiz Fuertes *and, most recently,* Land of the Eagle: A Natural History of North America.

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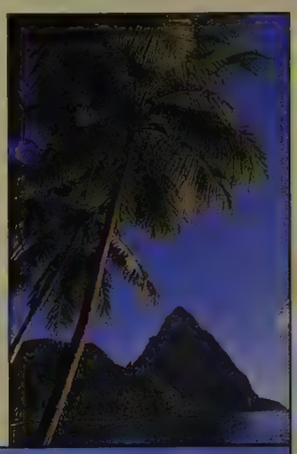

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At the American Museum

An Astronaut's View of Planet Earth

Donald Thomas, an astronaut with NASA Johnson Space Center, will present an illustrated talk on satellite studies of Earth in the 1990s. Thomas will discuss NASA's goal of understanding and predicting natural and human-induced changes in the planet's land, atmosphere, and oceans.

This lecture, on Thursday, August 6, at 7:30 P.M. in the Planetarium's Sky Theater, is the last in a three-part series hosted by the Hayden Planetarium in conjunction with the Museum's exhibit "Global Warming: Understanding the Forecast." Tickets are $8 ($6 for members). For information about ticket availability and other planetarium events, call (212) 769-5900.

Origami Folding

An origami event will take place daily from Monday, August 3, through Sunday, August 16, during Museum hours. Expert folders will be available in the Hall of Ocean Life to teach Museum visitors to make a variety of origami shapes, from balls and balloons to swans and jumping frogs.

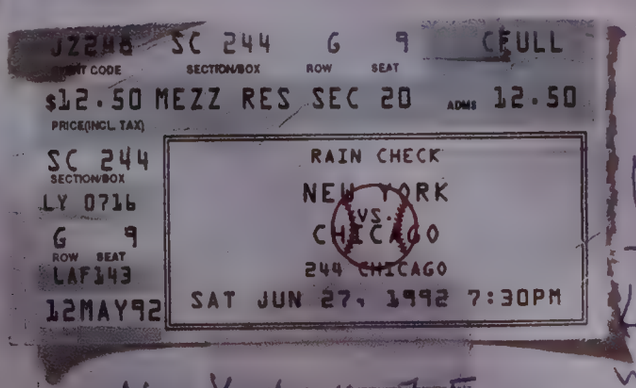
Naturemax

Through Saturday, October 31, Naturemax Theater will be showing *Ring of Fire* (daily at 10:30 and 11:30 A.M. and 1:30, 2:30, and 3:30 P.M.) and *Blue Planet* (daily at 12:30 and 4:30 P.M.). *Ring of Fire* explores the 30,000-mile circle of volcanoes of the Pacific rim, while *Blue Planet* presents film footage from four space shuttle flights. On Fridays and Saturdays, in addition to the weekday schedule, *Ring of Fire* and *We Are Born of Stars* will be featured at 6:00 and 7:30 P.M. *We Are Born of Stars* is a 3-D film presentation on the evolution of the solar system. Call (212) 769-5650 for further information.

These events take place at the American Museum of Natural History, located on Central Park West at 79th Street in New York City. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

On display in the Museum's exhibition "Global Warming: Understanding the Forecast" is a "burping cow," representing the world's 1.3 billion dairy and beef cattle. Every time a cow burps (every minute or so), it expels a greenhouse gas, methane, into the atmosphere.
Craig Chesek; AMNH

New York is really cool. Today Dad and me got up before Mom and went to Central Park. We saw lots of joggers and rollerskaters. One guy did tons of tricks. Dad said maybe I could get a pair. Then we went back to the hotel and got Mom and went to the Intrepid. WOW! It's big! The guide said you could fit 3 1/2 football fields on the Intrepid. We also went to see the new Barosaurus at the American Museum of Natural History. It was awesome! On the way we saw a movie being filmed. I can't wait to tell Steve. We ate hot dogs & ices from a stand. And then we went to the World Trade Center. From the top we could see the Statue of Liberty and Ellis Island. That's where my great Grandma and Grandpa went through when they came to America. Dad says what we're doing tonight's a surprise. I hope it's a baseball game. I see why Mom keeps saying



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A Serious Candy

In the tropics, gastronomes are nuts about cashew apples

by Raymond Sokolov

At the entrance to a recent open-air food festival in the colonial fort at Santo Domingo, fruits and vegetables were piled up high to celebrate the coming quincentennial of Columbus's arrival in the New World. Santo Domingo is the capital of what is now the Dominican Republic, the Spanish-speaking eastern half of the Caribbean island of Hispaniola (Haiti is the western half), where Columbus established the first European settlement in the New World, having landed there just before Christmas in 1492. So it is no wonder that Dominicans are eagerly preparing for Columbus Day 1992, since for them it is not just a landmark in world history but a kind of local birthday. That food was used to symbolize the "encounter" that began on Hispaniola so long ago was particularly fitting, for the exchange of foods between the Americas and the rest of the planet is the most important positive result of Columbus's blundering "discovery."

At the Santo Domingo fort, the festoons of locally grown products exemplified this benign and creative culinary cross-fertilization. There were native guavas and chilies, as well as mangoes and bananas descended from Asian ancestors. And under nearby tents, restaurant crews were serving Creole dishes based on pork and goat and salt cod, ingredients originally imported from Europe.

Anyone who has spent time in island markets and food stalls could have easily named just about everything on hand. But there was one pile of red and yellow fruits that stumped me. At first glance, I thought they were somewhat wilted bell peppers. But on closer inspection I realized they were something I hadn't seen before. A Dominican friend picked one up and unhesitatingly identified it as a *cajuil*. This is not a word you will find in an ordinary Spanish dictionary or even in the polyglot lists of vernacular names in Alan Davidson's authoritative *Fruit*.

I tasted the fruit. It was juicy and astringent. The next night I deduced what it was. At a formal dinner, there was the same attractive, red tetrahedral object in a centerpiece in the middle of the table. I picked it up. Hanging from it was a kidney-shaped, dark green thing I knew in a flash was a cashew.

The cashew nut we eat in North America is, botanically speaking, the true fruit of the tropical evergreen tree *Anacardium occidentale*. But this is not the whole story. In nature, the cashew does not simply hang, as do most nuts, from the branches of its tree or slumber safely inside a fleshy or spiky outer envelope, like a chestnut or black walnut. After a certain point in its fruity career, the cashew nut's stem, or peduncle, swells and turns into a fleshy mass known in botany as a receptacle, or disc. This cashew "apple" is what I had been seeing in Santo Domingo.

Frankly, I couldn't work up a lot of excitement over the puckering taste or stringy texture of it. But then the next afternoon, I heard a child's voice call out, "Cajuil." There was no bright fruit this time. The girl was leaning out the window at the front of her house to sell me a black fruit preserve, which turned out to be made from the cashew apple.

This is a serious candy, sober both in appearance and in taste. I recommend it to anyone, especially anyone visiting in the colonial section of Santo Domingo, where cashew conserves are sold in little markets and may well be still available from the girl who lives across from the elegant stone church of Los Mercedes, whose doors open for mass in the early evening, offering refuge from the heat and a view of

two painted eighteenth-century baroque wooden altarpieces (*retablos*).

That cashew conserves should coincide with a colonial church in the Caribbean seems appropriate, since the trees were brought in from their native ground in Brazil as a byproduct of Spanish imperialism. And it also seems appropriate that modern Dominican gastronomes attempting to distinguish their cuisine from the generalized Creole cuisine of the Caribbean should display the cashew fruit and

In Brazil, where the cashew tree is native, the receptacle, or "apple," is as important a food as the nut that hangs from it.
Paula Lerner; Woodfin Camp and Associates

ple and claim them as jealously as they *habichuelas con dulce* (a sweet dessert ade of puréed red beans).

Many other cultures, from Mexico to dia, can now also call the cashew their vn, but the Brazilian origin is clear. any of the world's vernacular names for e cashew descend from the Amazonian ipi word *acajú*: *cajuil,* the Portuguese *ju,* the English cashew.

Brazilians know their cashews and con- me them in every conceivable way, as they have since before the arrival of the Portuguese. A sixteenth-century chronicler reported cashew trees in cultivation by Indians on the coast of Bahia and a wine made from the cashew apple (which is now called *pera,* or pear). Today, a cashew apple wine (*cajuada*) is still produced, and Brazil is the only country where the cashew apple competes with the nut as a consumer item. It is found in preserves and many other preparations, notably cashew apple juice (*cajuina*), which is three times as rich in vitamin C as its citrus equivalent. The nut, called chestnut, or *castanha,* is also a fundamental part of the cuisine. A delicious example of this Brazilian zest for the cashew, a kind of cashew fudge, showed up this year among the exotica in a Dominican-owned superette on West Ninety-third Street in Manhattan.

The cashew tree will grow in this country, but basically only in south Florida. It is tropical, as is its main economically useful

Cashew Punch

(Adapted from *Traditional Jamaican Cookery,* by Norma Benghiat, Penguin, 1985)

3 cups juice of cashew apple
Juice of 1 orange
Juice of 1 lime
Sugar

1. Combine the three juices. Add sugar to taste. Serve over crushed ice.

Yield: 4 servings

Cashew Jam

4 cups cashew apple, peeled and diced
4 cups sugar

1. Combine the diced cashew apple and the sugar. Cook slowly until the fruit is tender and the mixture will set.
2. Pour into sterilized jars and seal.

Yield: About 1 quart jam

Habichuelas con Dulce

(Adapted from *Cocinando con Chea de Ortiz,* by Mercedes Manzano de Ortiz, Editora Corripio, Santo Domingo, 1985)

8 ounces red beans
2 sticks cinnamon
10 tablespoons milk, approximately
½ pound batatas *(white-fleshed sweet potatoes), peeled and diced*
1 clove
Pinch of allspice
¾ cup canned coconut milk (available in Asian markets)
½ teaspoon salt
10 tablespoons sugar
¼ cup raisins (optional)
1 tablespoon butter

1. Let the beans soak overnight.
2. In a stockpot, combine the beans with 4 quarts water. Add 1 cinnamon stick, bring to a boil, and simmer slowly for 3 hours or until the beans have softened completely and can be easily mashed with a spoon. By the end of this process, the water will have almost completely evaporated. Be careful to stir and add water if necessary to prevent scorching. Add 6 tablespoons milk and let cool.
3. Discard cinnamon. Using the steel blade of a food processor, purée the beans.
4. While the beans are cooling, simmer the *batatas* with the remaining milk, cinnamon stick, the clove, and allspice. Cook until tender. Combine with the bean purée, coconut milk, and salt. Press through a strainer.
5. Place over low heat and stir constantly until the mixture begins to boil. Add the sugar (and the raisins, if used) and simmer for five minutes, stirring constantly.
6. Remove from heat and beat in the butter. If the mixture seems too thick, add more milk. Serve at room temperature.

Yield: 10 servings

relative, the mango. These fruit trees are both members of the Anacardiaceae family, which also includes the pistachio, poison ivy, poison oak, and poison sumac. You can see the family resemblance best by carefully cutting away the outer shell of a mango pit to expose the heart-shaped seed lurking inside the hollow space, much like a peach seed inside a peach pit. The mango seed looks almost exactly like a cashew nut.

Perhaps this similarity helped predispose people in India, where the mango is native, to eat the cashew nut when it was imported from Brazil to the Portuguese colony at Goa. Indians, who have traditionally made a flour from mango seeds, would have had no trouble experimenting with their cashew kin. And today, Indian cooks lead the world in ingenious culinary exploitations of the cashew. India is also the leading producer of the nut.

Especially in the south of the subcontinent, the cashew is ubiquitous. It appears in desserts and, ground to a paste, thickens luxurious sauces. It is chopped, fried, and added to breakfast cereal. Cookbook author Julie Sahni reminds us that cashews are a standard ingredient in the Mysore lentil-rice-vegetable specialty, the celebrated *bese bele* of Bangalore. At Kanchipuram, a Hindu center in the south, the cream-of-wheat dumplings called *idlee* are traditionally studded with cashews.

Indians have a highly developed repertoire of sweets and candies, among which cashews play a major role. One example is cashew *barfi,* a fudge. And at the summer feast in honor of their elephant-headed god Ganesha, a favorite treat is *kaju poli,* a sweet cashew-flour *poori,* or air-puffed fried bread.

Anacardium occidentale, *the cashew tree*
Jany Sauvanet; Photo Researchers, Inc.

The Portuguese also naturalized the cashew in Mozambique, and it became a major cash crop. The Spaniards took the nut across the Pacific from Mexico to the Philippines in the Manila galleons that opened up Asia to the Spanish imperial system in the sixteenth century. Most nut production even in these established centers is from semiwild small holdings, and the harvest is laborious. A typical yield weighs 100 to 150 pounds (apples and nuts together). Twenty pounds of this is unhulled nuts, which results in a mere six pounds of dried, raw white kernels; once roasted, they become the nuts we know and love.

Along the way, the cashew farmer faces a problem quite apart from the usual risks and labors of pomological enterprise. The family connection with poison ivy asserts itself in caustic nut shell liquid (CNSL), a toxic substance found on the inner hull of the nut, which contains cardol and anacardic acid (something like this also occurs in mango rinds) and can cause acute dermatitis, swelling, and blisters said to be far more serious than the lesions brought on by skin contact with poison ivy.

No one should eat green cashew nuts. But roasting eliminates the danger. The traditional method, open-fire roasting, is unhealthy for workers. Today, advanced modern methods remove the risk and save the CNSL, which is valuable in the manufacture of brake linings because it absorbs heat efficiently.

So every time you come to a safe stop at a red light, thank the cashew. But then, as you start up again, consider how you are missing out on cashew apples and their many byproducts, including the soft drink *cashola* and the brandy *fenni* from Goa, as well as *koniagi* from Tanzania, which Frederic Rosengarten in *The Book of Edible Nuts* describes as a "ginlike liquor."

In a well-run world, the true cashew lover, or anacardiophile, would drive home after a hard day at the office and mix a *koniagi* martini lightly stirred with a trace of cashew apple vermouth and garnished with one unsalted cashew nut instead of an olive.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

Perseus' Diamond Sword

by Gail S. Cleere

On any clear night you can see meteors streaking across the sky, but some nights are better than others, and the night of August 11–12 will be one of the best. Just after midnight the Perseid meteor shower will peak at a rate of about fifty to sixty meteors per hour. These meteors typically leave bright, multicolored traces across the sky and appear to emanate from the northernmost part of Perseus, hence their name. The Perseids can usually be seen at a quarter of the peak rate for two days before and after the maximum. This year the nearly full moon will slightly hamper viewing because it will not set until morning twilight.

The Perseid meteor shower is one of the oldest recorded. These fiery meteors may have inspired the Greek myth that the god Hermes gave Perseus a diamond sword to sweep across the sky. In A.D. 36, the Chinese recorded that "more than 100 meteors flew in all directions in the morning." Since medieval times, these meteors have been known as the tears of Saint Lawrence or the sparks of Saint Lawrence's grill. According to legend, in A.D. 258 the Roman emperor Valerian demanded that Lawrence bring him all the Christian church's treasures. Instead of presenting the treasures to the emperor, however, Lawrence presented him with the church's poor, and the emperor retaliated by having him roasted over a red-hot grill. The August meteors dependably show up on the date of Lawrence's martyrdom.

The Perseid meteors are remnants of Comet Swift-Tuttle, first spotted in 1862 from Rochester, New York, by renowned comet hunter Lewis Swift, who thought it was another, known comet he was searching for. A few days later, Horace P. Tuttle observed it from Harvard University and recognized it as a new comet. Orbital calculations made in 1866 revealed that Comet Swift-Tuttle traveled in the same orbit as the Perseid meteor shower. The comet's predicted return in the early 1980s was not observed.

Astronomer Brian Marsden, of the Harvard-Smithsonian Center for Astrophysics, speculates that Comet Swift-Tuttle could be the same comet that was observed in China in 1737 by the Jesuit priest Ignatius Kegler. Working this information into his calculations, Marsden believes that the comet may return this year in November. But he admits that this possibility is a long shot; his new arrival time assumes that some force other than gravity, such as outgassing from the comet's nucleus (which would act like rocket thrusters), has significantly altered the comet's orbital period.

Despite the mystery surrounding the comet, the Perseid meteor shower's orbital path around the sun is known with certainty. When the earth passes through the shower's path on August 12, debris left behind from the nucleus of Comet Swift-Tuttle (usually sand-grain-sized particles) will enter the earth's atmosphere, producing meteors, which are also known as falling or shooting stars. Meteors (which can also come from bodies other than comets) heat up from friction as they enter the earth's atmosphere. Of the millions of meteors that enter the atmosphere each day, most burn up, but larger objects do survive to reach the ground. Meteors from comets do not appear to have the bulk, or strength, to survive a trip to the ground.

THE PLANETS IN AUGUST

Mercury slips between the earth and the sun on the 2d, but by midmonth, this fast-moving planet is far enough away from the sun for viewers to spot it in the early morning. Mercury's greatest elongation west of the sun occurs on the 20th.

Venus appears very low in the western sky after sundown but is difficult to observe because of its proximity to the horizon (yet because of its brilliance it can be spotted if the horizon is unobstructed). As the year progresses, Venus will slowly climb higher in the evening sky.

Mars is now rising just after midnight in the constellation Taurus. About the 10th, the ruddy planet will be above the V-shaped group of stars called the Hyades and some five degrees above the reddish star Aldebaran, which was known as God's Eye to the ancient Hebrews.

Jupiter is visible in the west early in August just after sunset. On the 1st, look for the planet above and to the right of the crescent moon. By midmonth, Jupiter is too close to the sun to be seen easily in twilight.

Saturn reaches opposition on the 7th, rising as the sun sets and setting as the sun rises. Saturn is well placed for observation among the rather faint stars of Capricornus, just east of Scorpius and Sagittarius in the Milky Way. On the 12th, look for Saturn just south of the nearly full moon.

Uranus and **Neptune** remain in Sagittarius and are easily seen with binoculars on dark nights. To locate these planets, consult the special sky maps that appear in popular astronomy magazines. On the 10th, the waxing gibbous moon will be to the left of these blue-green worlds.

The **Moon** reaches first quarter on the 5th at 6:48 A.M., EDT; is full on the 13th at 6:27 A.M., EDT; reaches last quarter on the 21st at 6:01 A.M., EDT; and is new on the 27th at 10:42 P.M., EDT.

Gail S. Cleere writes on popular astronomy and is a founding member of the International Dark Sky Association, an organization dedicated to preserving the skies for astronomy.

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Woman drying papads *in the summer sun, Benares, India*

Adam Clayma

Crimes Against Nature

by David E. Powell

A decade or so ago, Adam B. Ulam, one of America's leading specialists on the Soviet Union, half-ironically posed the question: "Do we know all there is to know about the USSR?" In Ulam's view, a Westerner who really wanted to could understand that country's politics, economics, and society. He was right. A careful reading of Soviet newspapers, magazines, and scholarly journals—even during the Brezhnev era, when censorship abounded and the country was mired in "stagnation"—permitted anyone with sufficient interest and energy to grasp the essence of Soviet life.

One of the most accomplished practitioners of the art of ferreting out valuable information from fugitive Soviet sources has been Murray Feshbach, formerly of the U.S. Census Bureau's Foreign Demographic Analysis Division and currently professor of demography at Georgetown University. Feshbach was, and still is, legendary for his ability to obtain access to publications issued in editions of only a few hundred (or a few dozen) copies, to establish contact with a wide range of official and unofficial sources, and to help the rest of us understand the importance of developments about which we were only dimly aware.

ECOCIDE IN THE USSR: HEALTH AND NATURE UNDER SIEGE, by Murray Feshbach and Alfred Friendly, Jr. *Basic Books, $23.00; 376 pp.*

Now, with the profusion of data coming out of the former USSR, he is in his element. With Alfred Friendly, Jr., a former correspondent for *Newsweek* and the *New York Times*, Feshbach has put together a compendium of facts and commentary (liberally quoting the observations of officials, scientists, journalists, and environmental activists in Russia, Ukraine, and other former Soviet republics) that will tell readers virtually everthing they would ever want to know about the status of public health and/or the environmental situation in the former USSR.

The authors' message is almost unreservedly gloomy. Indeed, the very first lines of the book read: "When historians finally conduct an autopsy on Soviet Communism, they may reach the verdict of death by ecocide.... No other great industrial civilization so systematically and so long poisoned its land, air, water and people. None so loudly proclaiming its efforts to improve public health and protect nature so degraded both." Relentlessly, but relying scrupulously on evidence obtained from Soviet sources, including interviews with ecological specialists in the USSR (or certain states created from the former USSR), Feshbach and Friendly document their case thoroughly. So well do they buttress their arguments that I suspect some readers will be numbed, unable to distinguish what is merely appalling from what is genuinely tragic.

Shortly before the breakup of the Soviet Union, one member of the USSR Academy of Sciences described official policy toward the environment as "an ecological crime...ecological genocide." Another academician, writing at about the same time, declared that those in charge of the economy "behave toward nature like conquerors in a foreign land." Yet another eminent scientist concluded that "the entire territory of the country is an ecological disaster zone." These are not the rantings of the lunatic fringe; these are the observations of some of the (former) USSR's most distinguished scientists.

How could this tragedy have occurred? One might have expected the Soviet Union and its leaders to be in a preeminent position to preserve and enhance nature's gifts. Having seen capitalism's terrible blunders, the authorities, who dictated production priorities and selected appropriate technologies, and in the basic sense, controlled all political and economic decisions, could have enforced their will on any problem facing the nation.

But the Soviet leaders were never interested in balanced growth; these socialist industrialists, no less than their capitalist counterparts, showed themselves to be capable of despoliation on a massive scale. Indeed, centrally determined priorities, allocations, incentives, rewards, and punishments meant an excessive fixation on production at the expense of all else and an undervaluation of such basic resources as land and water ("free goods," as they were known). Factories and farms were encouraged to deal with the environment through the "residual principle"—that is, capital investment and operating costs were allocated to insure production, and only if any funds were left over were the needs of nature considered.

Take, for example, the damage done to the nation's streams, lakes, rivers, and seas. Constantly assaulted by industry and agriculture, and given little protection by their nominal custodian (the Ministry of Land Reclamation and Water Resources), they were aptly described by *Izvestia* during the Gorbachev years as "having been reduced to a lamentable condition." (In 1989, water-pollution levels at more than one-third of the sites monitored by the USSR State Committee for Environmental Protection exceeded the maximum allowed by a factor of ten or more.)

Even Siberia's Lake Baikal, one of nature's grandest treasures, continues to suffer "barbarous exploitation," asserted a prominent Soviet analyst not long before

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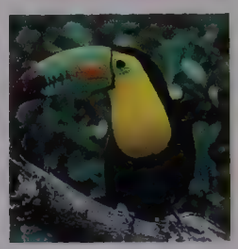

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the Communist regime was toppled. Every year, factories dumped millions of tons of waste water containing zinc, mercury, tungsten, molybdenum, and other poisonous substances into Baikal—despite dozens of official resolutions, decrees, proclamations, and promises. Some 700 agricultural facilities—livestock pens, sheds containing fertilizer or chemicals, and so on—also poured caustic organic chemicals and fuel oil into the lake.

The Communist system was equally profligate with its use of the land. The system of collective and state farms was a tragedy in many ways: the peasants were hardly a powerful political constituency, and the land that had once belonged to them (or to their forebears) was treated with very little respect. No less a figure than Mikhail Gorbachev told a Party Central Committee session in March 1989 that over the previous twenty-five years, some 54 million acres of developed plowland had been lost. Thirty million acres were given over to industrial construction and roads; the rest, including some of the country's most fertile meadows and pastures, disappeared beneath what he termed "poorly thought-out projects" for dams, reservoirs, and hydroelectric power stations, or was simply abandoned.

Construction projects designed to regulate the flow of water or to "improve" the land were seen as an end in themselves, even though such designs often required the "drowning" of prime farmland. At the same time, teams responsible for planting trees frequently found their work undone by farm managers who believed that "unproductive" use of the land would interfere with the fulfillment of agricultural production quotas. The harvest inevitably took priority over planting trees, even though the latter could have prevented erosion and flooding; similarly, "the plan" took precedence over crop rotation and other efforts to prevent depletion of the soil. Topsoil and the earth beneath it were regularly washed away. Animal fertilizer was generally kept in containment tanks located close to rivers and streams—an arrangement that regularly helped to bring about ecological catastrophes. As one Russian analyst put it, "A heavy rain—not to mention the spring floods—is enough to send an avalanche of accumulated poison cascading into the river."

Nowhere has the link between the misuse of the land and filthy water been manifested more clearly than in Central Asia. There, a combination of unfiltered drinking water, untreated sewage, and large quantities of pesticides, herbicides, defoliants, and fertilizers has done massive damage to the population's health, not to mention causing severe economic losses. For decades, pure water from the region's rivers has been diverted to irrigation projects (especially for cotton), and the water remaining in rivers and streams is almost always badly polluted. Noting that more than three billion cubic meters of agricultural, industrial, and human waste flowed into the Amu-Dar'ya each year, the minister of health of Soviet Turkmenia described that waterway several years ago as "little more than a sewage ditch." Even today, however, local residents—including children—take their drinking water from the Amu-Dar'ya.

A large portion of the Feshbach-Friendly volume details the health crisis that the USSR and its successor states have had to confront. Some of the material may be familiar to readers of *Natural History,* as the U.S. government, the European Economic Community, the International Monetary Fund, and the World Bank debate emergency aid to the former Soviet Union. But Feshbach and Friendly go far beyond the superficialities of mass-media debate. Again, by utilizing official statistical compendiums, newspaper articles, interviews with officials, and the statements of outraged Russians, Ukrainians, and others, they carefully outline the dimensions of the country's (or, more properly, the countries') public health problems.

They point out that the Soviet government's failure to invest effectively in health care and environmental protection "brought the average life expectancy of its citizens down to the average life expectancy in Paraguay" (63.8 years in 1989). In 1990, the life expectancy of Muscovites was ten years below what it had been in 1979, and Moscow was ranked seventieth out of the world's ninety largest cities. The authors cite other horrific data: At the end of 1990, almost half of all rural hospitals and polyclinics had no sewer connections, 80 percent had no hot water, and in nearly 75 percent between six and fifteen patients were squeezed into four-bed wards. Similarly, X-ray machines were available in only half of all hospitals in the country, and only 2 percent of these health-care institutions had the equipment to perform ultrasound tests.

In Central Asia, the situation is even worse: Feshbach and Friendly cite a 1989 report on obstetrician-gynecologists in

ne province in Turkmenia. This docu-
ent revealed that 70 percent of the spe-
alists lacked surgical skills; as a result,
alf their patients who underwent surgery
ied. According to the report, follow-up
udies of the "deceased pregnant women,
ecently confined women and gynecology
atients make it clear that two out of every
ree deaths could have been prevented."

To cite additional examples would be
epetitious, but the interested reader will
nd them in abundance. What, then, is one
o make of the book? It obviously demon-
rates scrupulous research and an ency-
lopedic knowledge of the Soviet Union,
s component parts, and its successor
tates. It tells its story—one that has some
f the same traits as a Greek tragedy—
owerfully and persuasively. The two au-
ors are to be commended, even ap-
lauded, for a remarkable achievement.

Nonetheless, I have two criticisms.
irst, it is sometimes difficult to grasp the
ull significance of certain information, es-
ecially when comparative data are lack-
ng. Knowing how many tons of soot fall
n Magnitogorsk or how much untreated
vaste is allowed to wash into the Baltic
nd Black seas is only helpful if we know
omething about the situation in New
ork, London, or Venice.

Second, the authors give too little atten-
on to the emergence of a "green" move-
ent in various parts of the former USSR.
o be sure, they point out the crucial role
layed by environmentalists in Lithuania
nd elsewhere—brave men and women
vho challenged the old authorities and the
ld priorities. But the Soviet Union no
onger exists, and leaders such as Boris
eltsin are seeking to introduce political
emocracy and a market economy. What
re the ecological implications of these
hanges? Socialism certainly failed to pro-
ect the environment, but has capitalism
nuch to be proud of? What kinds of poli-
ies toward the environment are we likely
o see in the states that once made up the
oviet Union?

I must emphasize, though, that these are
inor complaints. They do not detract sig-
ificantly from a major contribution to our
nowledge of the USSR and its successor
tates, as well as health care and environ-
ental protection more generally. This is
n important book that deserves to be read
idely.

David E. Powell is a fellow at the Russian Research Center and a lecturer at the School of Public Health, both at Harvard University.

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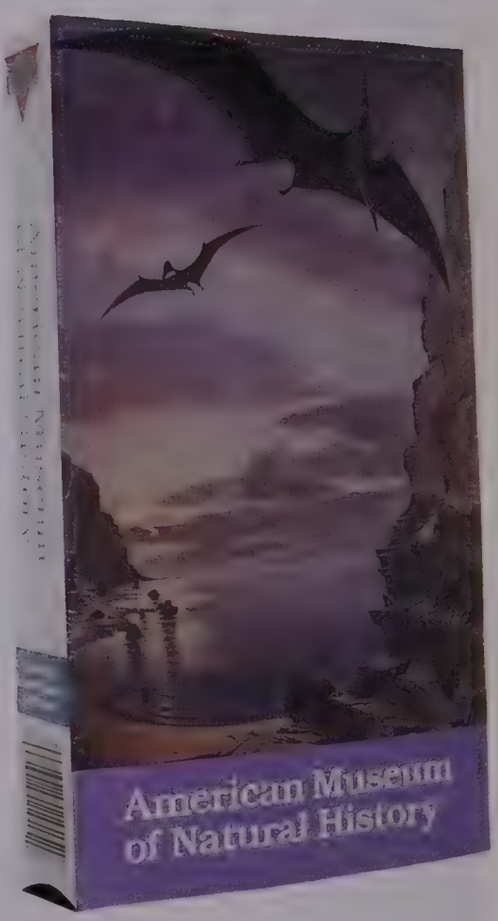

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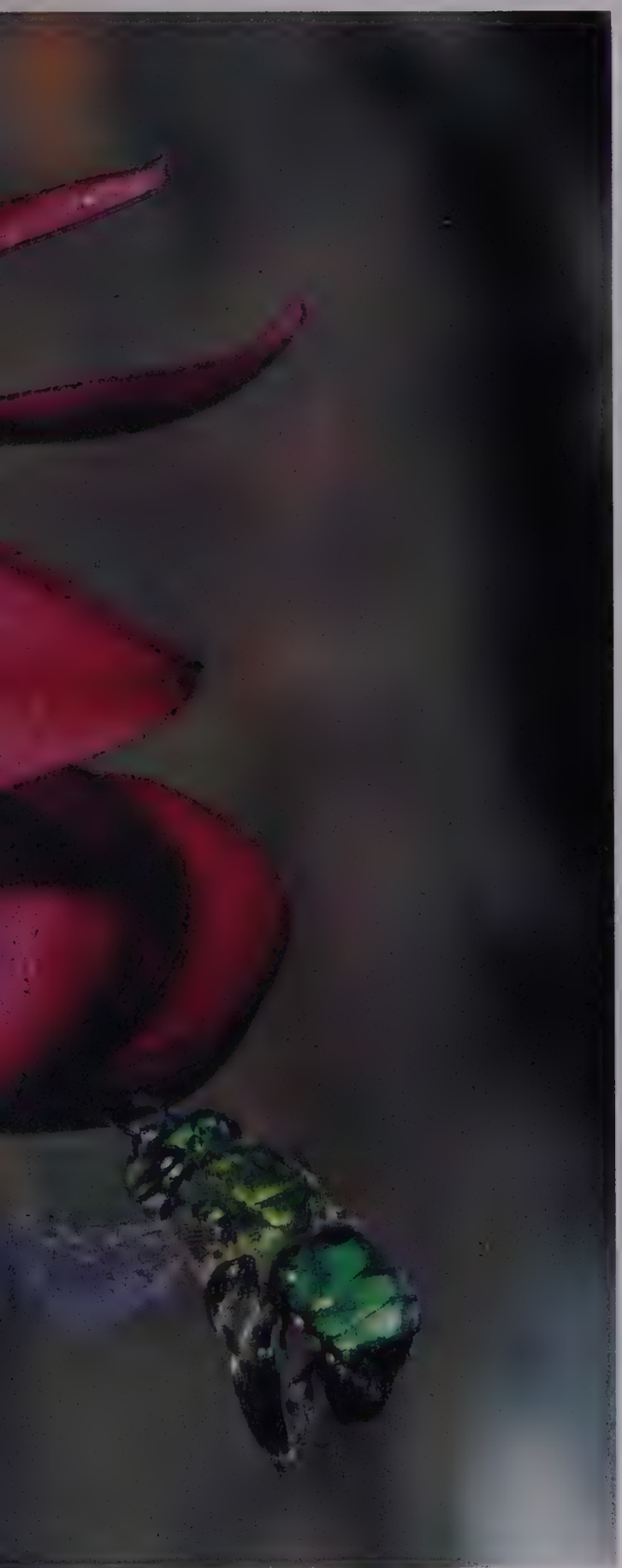

For Male Bees Only

On a riverbank in Costa Rica, jewellike orchid bees (genus *Euglossa*) visit a blossom. In addition to the ruby- and emerald-colored species shown, bright orange and indigo bees also hover around the flowers. The orchid, a species of *Mormodes,* offers neither nectar nor useable pollen, but the flower's aromatic oils lure male orchid bees from the surrounding rain forest. (The attraction is so powerful that to catch these swift, elusive bees in the forest canopy, entomologists bait traps with cotton balls soaked in similar aromatics, such as oil of eucalyptus, wintergreen, and citronella.) Because the compounds closely resemble the male bees' sex pheromones, entomologists believe that the bees gather the oils to manufacture the chemicals they need to attract females.

While gathering the chemicals that promote their own reproduction, the bees inadvertently pollinate the flowers. Charles Darwin, intrigued by the elaborate pollination mechanisms that had evolved in orchids, was the first to figure out how the twenty or so species of *Mormodes* reproduce. Once attracted by the odor, a bee landing on the flower's lip may trigger a hinged appendage that strikes the insect's back. Two masses of pollen at the tip of the appendage break free and become cemented to the bee's back, ready to be transported to the next orchid.—*R. A.*

Photograph by Kamaljit S. Bawa

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AUTHORS

Erika Friedl (page 34), a professor of anthropology at Western Michigan University in Kalamazoo, describes herself as "one of the fortunate people for whom job, hobby, and diversion are one." Since she was a teen-ager in Vienna, Austria, she has been intrigued by "all things Middle Eastern and by watching people." She is usually involved with one or the other—or both—when she is not teaching or writing or hiking in the woods of Michigan. In the course of her ethnographic fieldwork in Iran during the last twenty-five years, she became especially interested in the role of children and in the philosophies of women. One outcome of her work is her book *The Women of Deh Koh: Lives in an Iranian Village* (New York: Viking Penguin, 1991). Friedl notes that very little has been written on children in Iran, or in the Third World generally, but recommends *Javady Alley,* a study of a poor Iranian family, by Manny Shirazi (London: Women's Press, 1984), and Robert Coles's series, *Children of Crisis* (Boston: Little, Brown and Company, 1973–1980), which pioneered enthnographic-cognitive research on children in the United States. Friedl is pictured here with children in the village of Deh Koh.

"I get paid peanuts, so I have to enjoy what I am doing," says **Johan T. du Toit** (page 28), who studies the ecology of southern Africa's savannas. While living in South Africa's Kruger National Park, a reserve about twice the size of Yellowstone, du Toit noted that when the knobthorn acacias burst into blossom each dry season, the giraffes would suddenly abandon the green vegetation along the rivers to feed on the trees' flowers. This curious behavior eventually led him to suspect that the giraffes were pollinating the acacias. Du Toit, who was born in Marondera, Zimbabwe, received his Ph.D. in animal ecology in 1988 from the University of the Witwatersrand in Johannesburg, South Africa. He is currently a lecturer on the ecology of large mammals at the University of Zimbabwe. In addition to publishing his work on the feeding habits of browsing mammals in Kruger, du Toit is hoping to get a grant to finish his research on giraffe pollination of acacias. He is also interested in elephant conservation on the tribal pastoral lands in northwestern Zimbabwe. For additional reading on pollination by mammals, he suggests "Pollination by Lemurs and Marsupials," by R. W. Sussman and P. H. Raven (*Science,* vol. 200, 1978, pp. 731–36).

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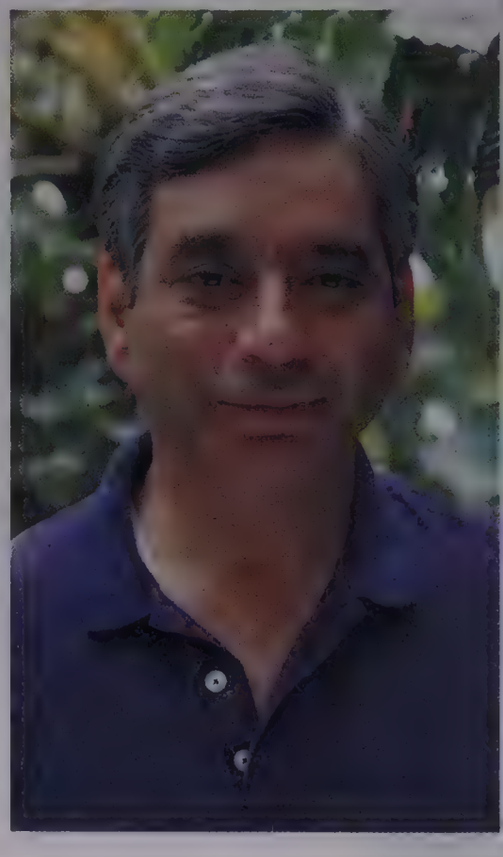
If **George Hendry** (page 46) could be granted a "magic wish," he would ask to be transported 50 to 300 million years into the past to get a firsthand look at ancient climates and "early moves" in the evolution of plants and animals. "I would even be content with ten minutes at 100 million years ago," he writes. A native of Scotland, Hendry lives and works in England, where he is an honorary lecturer and a research scientist in the Unit of Comparative Plant Ecology at the University of Sheffield. His research has centered on such questions as how plants process oxy-

gen and how they survive stress. Future plans involve taking similar concerns to a global level: How will the earth's vegetation respond to atmospheric warming and an increase in ultraviolet radiation? For more information on the double-edged nature of oxygen, he recommends the "readable and authoritative" *Free Radicals in Biology and Medicine,* by Barry Halliwell and John M. Gutteridge (New York: Oxford University Press, 1990).

John P. ("Alex") Alexander (page 54) admits to an obsession with the life and times of *Notharctus,* a cat-sized prosimian that leaped through the trees of North America some 50 million years ago. Shown here with his fossil mount of the creature, Alexander can usually be found in the Museum's Department of Vertebrate Paleontology, where he has been the collection manager of fossil mammals since 1983. With degrees in anthropology from the University of Arizona and Hunter College of the City University of New York, he has collected fossils in Arizona, Wyoming, Oregon, New Jersey, and Texas. In his spare time, he illustrates science fiction tales and is proficient at knapping his own "Paleolithic" chipped tools from flint and glass. Alexander commutes to the Museum from Astoria, Queens, on a mountain bike, dressed in black Kevlar body armor and a helmet of his own devising, which has built-in, mouth-operated directional signal lights. He claims he is "known to the New York Police Department as the Road Warrior." For further reading on early fossil hunting in Wyoming's Bridger Basin, he recommends *The Bone Hunters,* by Carl Lanham (New York: Columbia University Press, 1973). A good overview of living and fossil primates is given in *Primate Evolution,* by Glenn C. Conroy (New York: W. W. Norton and Co., 1990).

While conducting fieldwork in Costa Rica, **Kamaljit S. Bawa** (page 76) happened on an orchid surrounded by four differently colored species of *Euglossa* bees—metallic red, green, orange, and indigo. But when he tried to photograph them, he was unable to capture more than two in the frame at one time. Bawa has been interested in plant–animal interactions ever since the early 1960s, when he began fieldwork for his doctoral thesis in the tropical forests of his native India. Since then he has done extensive work on the reproductive biology of tropical forest plants. A professor of biology and a Pew Scholar in Conservation and the Environment at the University of Massachusetts at Boston, Bawa is now studying the effects of deforestation and habitat fragmentation on genetic diversity in rain forest trees of Costa Rica and Sri Lanka. The photograph for this month's "Natural Moment" was taken with a Nikkormat camera and a 105mm lens.



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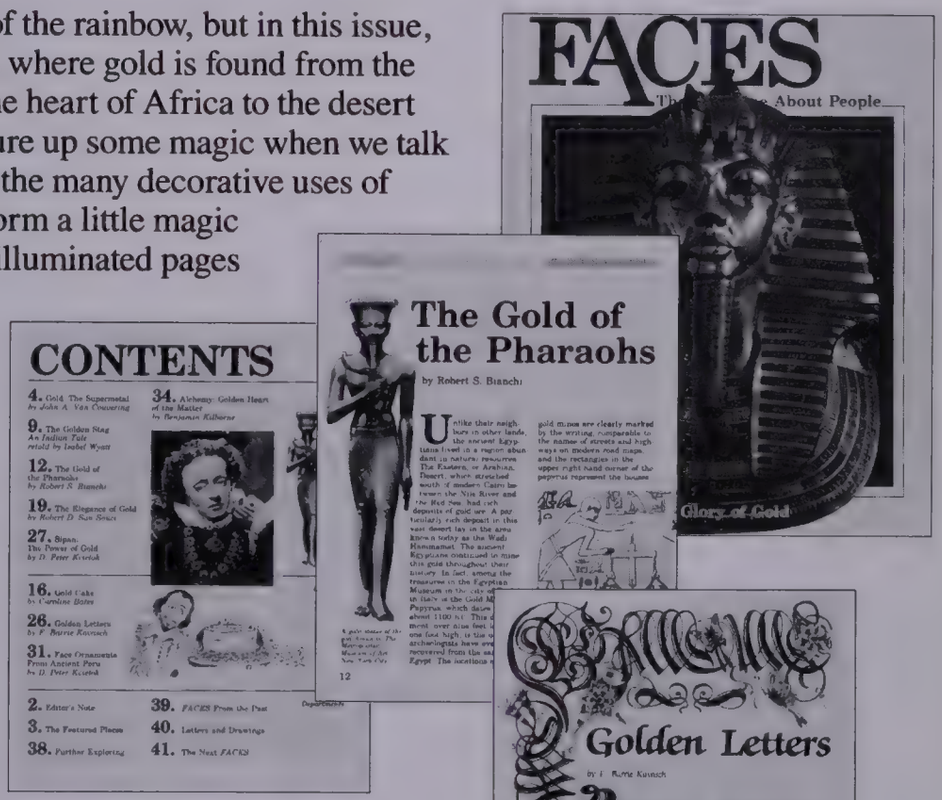

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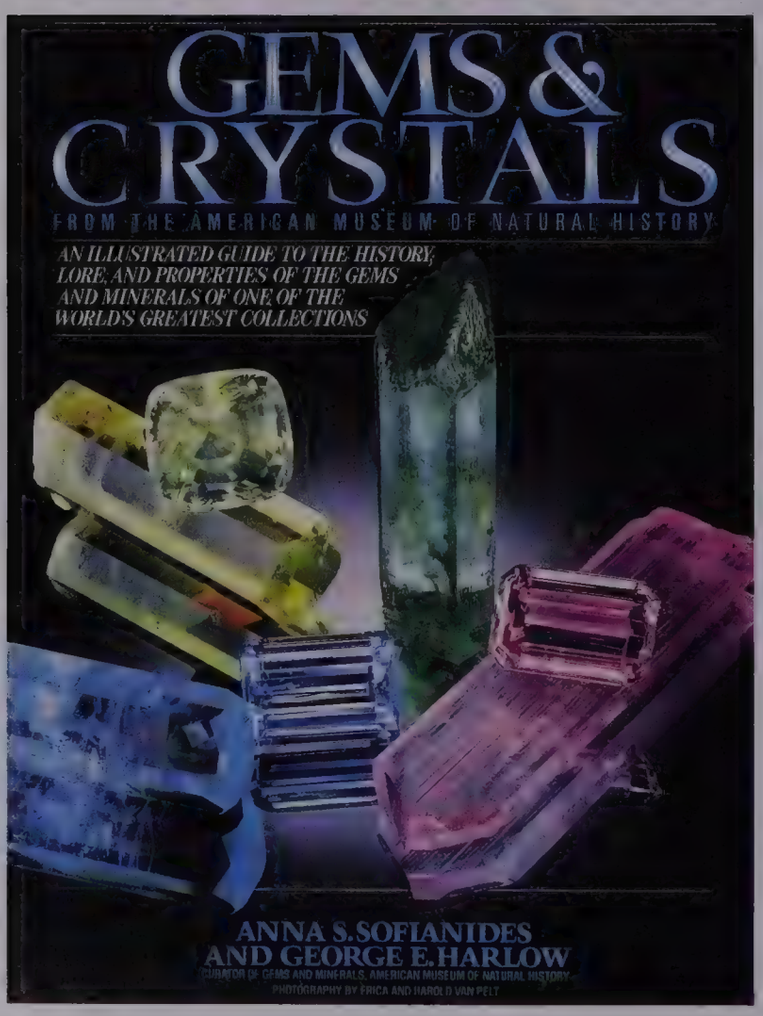
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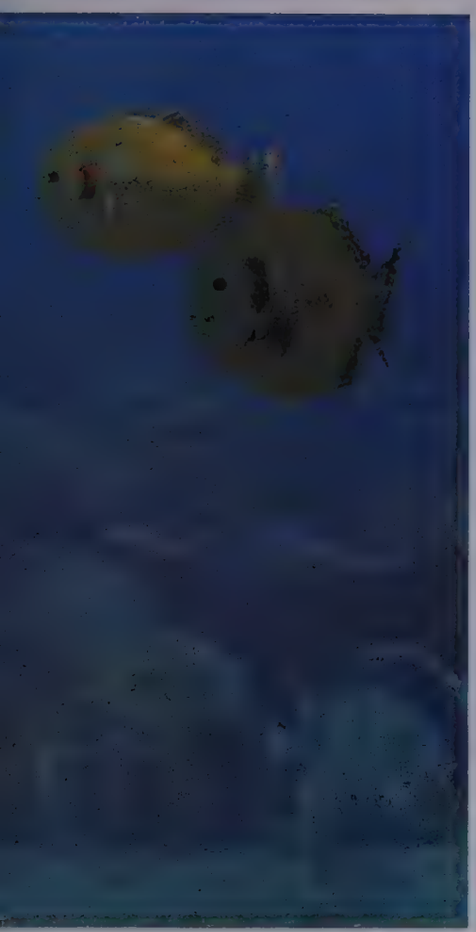

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Withering Heats

Global warming will be the last straw for many threatened species

by Andrew Dobson

Last September, a remarkably well-preserved 5,000-year-old man was removed from a glacier near the Austrian-Italian border. For reasons unknown, he had died huddled in a small trench and was then freeze-dried by the frigid air and engulfed in glacial ice. Ice Man, as he is known, may be the first of a string of lost Bronze Age alpinists to come to light as glaciers continue their rapid retreat up mountain valleys—an exciting prospect for archeologists. But for the rest of us, the shrinking glaciers are an ominous sign that we are entering another period of global warming—one brought on by human activities.

A special exhibition, **Global Warming: Understanding the Forecast,** will be on display at the American Museum of Natural History through January 17, 1993. The exhibit, jointly produced by the Museum and the Environmental Defense Fund, will then travel to Los Angeles, Pittsburgh, Denver, Saint Louis, Washington, D.C., and other cities.

The last warming, which ended several millennia before Ice Man perished, was part of the natural climate swing between glacial and interglacial conditions. Following 100,000 years of the coldest climate our planet has experienced and lasting some 10,000 years, it melted the vast ice sheets that covered much of the northern continents and left only glaciers in the high mountains. As the ice retreated, entire ecosystems were transformed.

As North America warmed, open spruce forests shifted northward and grew more dense; hardwood forests and grasslands replaced them. A great many plant and animal species vanished as the mean global temperature rose a mere 9° F. Mastodons, saber-toothed cats, giant ground sloths and armadillos, native horses and camels, and others—almost three-quarters of the continent's large mammals—all became extinct during this period. Although overhunting by humans (who had recently migrated across the Bering land bridge) has been blamed for the extinction of the large mammals, radical changes in the environment probably contributed to their demise.

Despite the difficulties of proving that a new warming is already upon us (*see* "Global Warming on Trial," *Natural History,* April 1992), most climatologists are now satisfied that greenhouse gases, including the carbon dioxide released from burning fossil fuels and forests, will warm the lower atmosphere. They expect carbon dioxide levels to double by the middle of the next century and average global temperature to rise 2° to 9°, with the largest changes at the poles and more moderate ones at the equator. (For much of life's existence on the planet, even warmer temperatures have prevailed; when the dinosaurs roamed, the global climate was a steamy 27° F warmer than it is today.)

Much has been said about the warming's possible effects on agriculture, water supplies, and sea level, all of which may affect human communities, but what about the rest of the natural world? Will global warming increase the already high extinc-

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The isolated ranges of Nevada's Great Basin National Park are among the mountainous regions that will lose biodiversity as rising temperatures force species to retreat uphill into shrinking habitats.
Jeff Gnass Photography

tion rates caused by the rapid destruction of rain forests and other habitats?

Predicting how a particular species will fare as the world warms is exceedingly difficult. Computer models of the earth's climate provide only a rough idea of the temperature changes that may befall any region. They do show, however, that the warming will be uneven and that the greatest temperature increases will occur in the polar regions. We also know that rainfall will change significantly as the planet heats up.

As the climate warms, plants and animals that can tolerate temperature extremes and drought will be relatively unaffected. They may even expand their ranges. But those that are adapted to live within a narrow set of climatic conditions will suffer. Portions of their current ranges may become too hot or dry, restricting them to increasingly small patches of land.

In the Northern Hemisphere, the survival of the more sensitive plants and animals will depend on their ability to adapt or expand their range northward at rates that compensate for the warming. A shift of sixty to a hundred miles toward the higher latitudes will compensate for a 2° rise in global temperature. But because the warming is expected to occur far more rapidly than previous climate changes, organisms will have little time to adjust. Many animals may be able to shift northward, but for plants—which most other organisms rely upon for food—picking up and moving is a less viable option. Forests are particularly vulnerable to climate change. Using fossil pollen to reconstruct past distributions of deciduous trees, Margaret Davis, an ecologist at the University of Minnesota, has found that trees migrate at maximum rates of 125 miles a century, with 6 to 25 miles being more typical. Plants that reproduce with spores or whose seeds are carried by birds may be able to keep up with the change, with migration rates of 20 miles or more in a single year. But trees and other plants with heavy seeds that drift only a short distance on the wind will not be able to keep up with the rapid warming, which would require them to shift as much as several hundred miles in less than a century.

A computer simulation by Jerry Leverenz, a plant physiologist at the University of Umea, Sweden, and Debbrah Lev, a graduate student at the University of Washington, showed what might happen to Douglas firs in the early part of the next century. Without the winter chill in the lowlands of Oregon and northern California, the firs' seeds would no longer germinate and spring growth of new shoots would cease. If the heavy rainfalls along the coast diminished, the growth rate of the remaining trees would slow. Although they would continue to grow at higher elevations, the firs would be replaced by other trees in the lowlands of the Sierra Nevada and the coastal ranges, completely changing those forest ecosystems. (Because the Douglas fir is the lumber industry's most important species its decline might appear to affect the Pacific Northwest's economy, but by the end of this decade most of the remaining trees will have been logged or will be protected in nature reserves.)

A preliminary study undertaken by Hank Shugart, of the University of Virginia, suggests that a doubling of atmospheric carbon dioxide could change vegetation over about 30 percent of the earth's land surface. Shugart's model predicts a shrinking of subtropical forests, boreal forests, polar deserts, and tundra and an expansion of savannas, tropical rain forests, and hot deserts. As plants are slow to colonize a new area, the losses are likely

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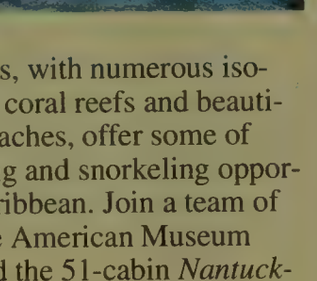

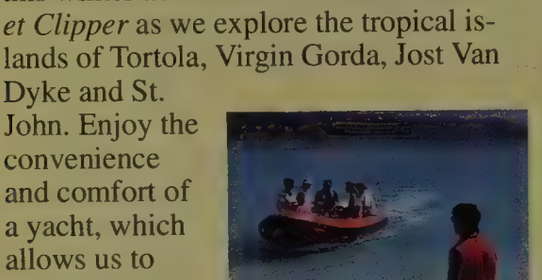

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to occur more rapidly than the expansions. As different species disperse at different rates, we will see considerable scrambling and reorganization of forest communities.

Some animals will surely disappear along with their habitats. Daniel Botkin, a forest ecologist, and his colleagues at the University of California at Santa Barbara believe that the Kirtland's warbler—a small yellow-and-gray songbird—may be one of the first species to become extinct as a direct result of global warming. The 400 or so surviving birds nest on the ground beneath the low branches of young jack pines in a small region around Grayling, Michigan, where well-drained, sandy soil prevents rainwater from flooding the warblers' nests.

The warblers' habitat has been in decline for some years, because the young pines grow only after fires, which are now suppressed. Global warming, however, is likely to eliminate the jack pines in this part of Michigan; the trees are extremely sensitive to changes in temperature and soil moisture. If the climate warms as expected, in about fifty years quaking aspens and oaks will replace the pines along the southern margin of their range. The warblers cannot gradually shift their nesting sites northward because they are unlikely to find jack pines growing in sandy soil. Unless extraordinary measures are taken to maintain the warblers' habitat or to transplant them to similar habitats far to the north, the species will become extinct.

Least threatened by warming may be the plants and animals living in high mountains, which would seem to have an advantage in the face of global warming. First, mountain habitats have escaped much of the development and fragmentation suffered by low-lying regions. Second, a relatively short move up a steep slope puts an organism in a substantially cooler "microclimate." (A 1,500-foot climb compensates for a 5° increase in temperature.) On the other hand, the available space decreases toward the mountain peaks. Dennis Murphy and Stuart Weiss, conservation biologists at Stanford University, have studied the animal populations in the mountains of Nevada's Great Basin, and they predict that the habitats occupied by upwardly mobile species will shrink so much with a 9° increase in temperature that 10 to 50 percent of the mammal species will disappear from the area.

In the Great Basin, the plants and animals live on mountain ridges that are essentially islands. Rising thousands of feet above the desert floor, one group of mountains is isolated from the next by stretches of hot, barren land. Such natural barriers have always isolated populations and contributed to species extinctions in the face of change. But now the world is further fragmented by expanding agricultural and urban areas. Species once free to migrate across continents as climate changed are now trapped in islands of wilderness.

Over the long haul, genetic adaptation has allowed many plants and animals to survive and evolve as new situations arose. Climate change is just one of the many pressures that have favored some individuals over others, driving evolution—the slow process that has led to the rich diversity of life. With rapid warming however, there will be little time for new genetic variations to arise through mutations or recombination; the ability of a population to adapt will therefore depend on its present level of genetic variability. For example, as temperatures rise, a few individuals of a population may already carry in their genes some trait that will give them an advantage over the others in warmer conditions. In the laboratory under artificial selection, such beneficial traits usually spread throughout a population within twenty to thirty generations and then rapid adaptation ceases. Those species with the most genetic variability to draw upon—and therefore best prepared to cope with climate change—are those with large populations spread over wide geographic ranges. But few of these species are threatened. Most endangered species have restricted ranges and are often fragmented into small populations with reduced genetic variability.

Species that are adapted to environmental stress might seem to have an advantage in a world of rapid climate change, but this is not necessarily the case. Desert animals, for instance, are adapted to require less water than similar-sized species living in less arid habitats, but they achieve this with reduced metabolic rates. Ary Hoffman and Peter Parsons, entomologists at the University of Adelaide, have found that in numerous animals, from fruit flies to cattle, greater resistance to a variety of stresses is genetically linked to lowered metabolic rates. Fruit flies bred to resist desiccation developed tolerance to a range of other stresses, such as starvation, heat shock, and toxic concentrations of organic poisons, but they also grow and reproduce at lower rates than other flies. Organisms with low metabolisms use scarce resources for maintenance and survival which allows them to cope with environ

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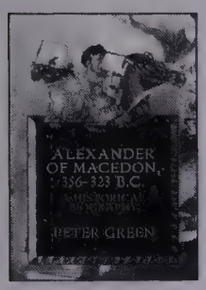

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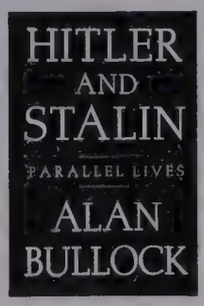

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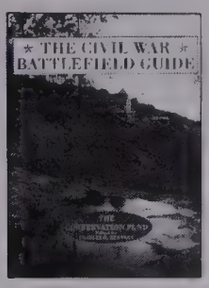

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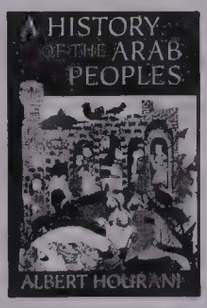

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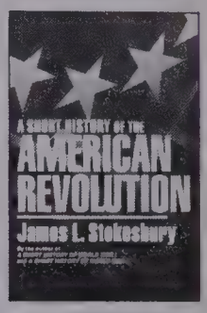

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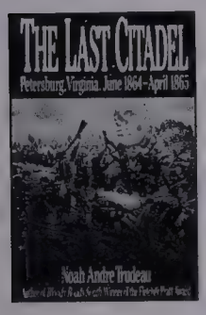

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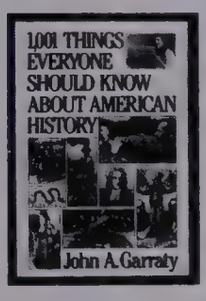

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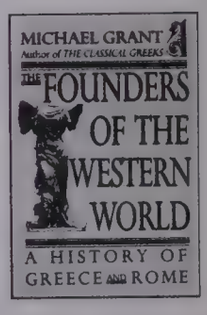

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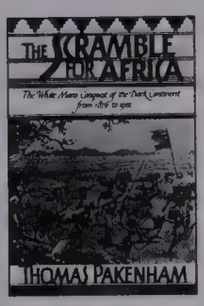

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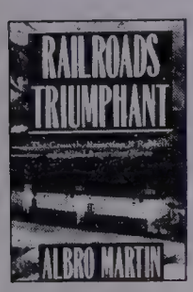

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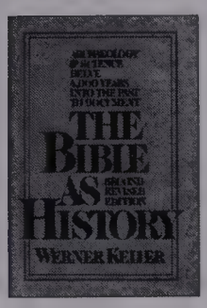

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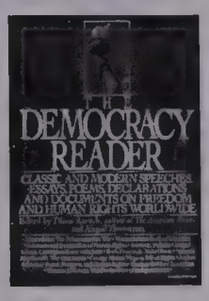

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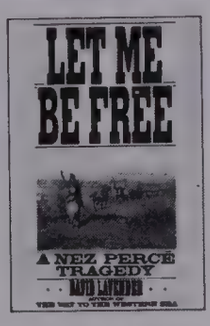

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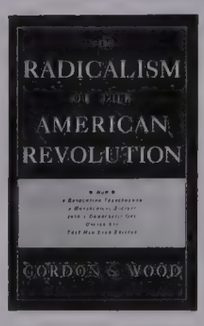

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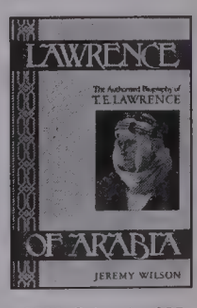

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mental extremes, but slow growth and low fecundity is the price they pay. Thus, if human intervention is required to help a species cross habitat barriers, individuals should be taken from across the species' range; this will insure that the genes from more resistant marginal populations, as well as those from more fecund individuals near the center of the range, will be passed on.

Climate change will also affect competition between species. In the late 1940s, Charles Park, an entomologist at the University of Chicago, conducted his classic experiments on competition between two species of flour beetle, showing that they could coexist only within a narrow range of temperature and humidity. Under hot, moist conditions one species consistently dominated the other, while under cool, dry conditions the outcome was reversed. Climate, therefore, can tip the balance in favor of one species over another, playing a crucial role in determining which species will increase its numbers and which will fade into extinction. In complex natural communities, the outcome of even simple competition is likely to be compounded by the cascading effects that result from subtle and intricate ways in which species are joined together in food webs. Small changes that diminish the competitive edge of one species may be magnified by predator–prey and host–parasite interactions, causing extinctions in other parts of the food web.

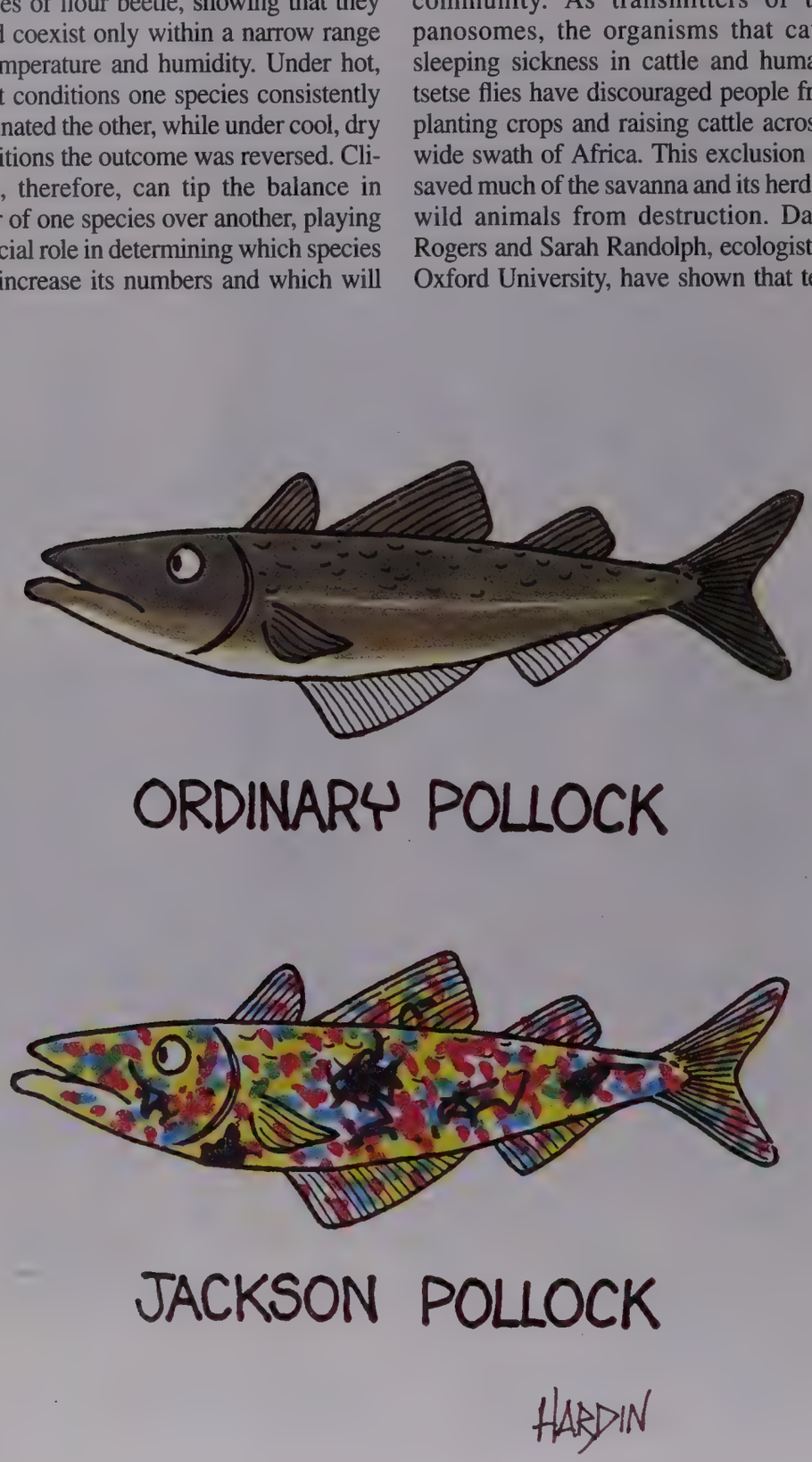
Tsetse flies provide an excellent, if somewhat unusual, example of how the demise of a single species may affect the structure and integrity of a whole animal community. As transmitters of trypanosomes, the organisms that cause sleeping sickness in cattle and humans, tsetse flies have discouraged people from planting crops and raising cattle across a wide swath of Africa. This exclusion has saved much of the savanna and its herds of wild animals from destruction. David Rogers and Sarah Randolph, ecologists at Oxford University, have shown that temperature and humidity are crucial in determining the range of tsetse fly populations. A temperature change of less than 4° could shift the flies' distribution significantly over the next fifty years. Tsetse numbers may decrease in much of central Africa, opening up large areas for cultivation and ranching and thereby reducing biodiversity in the Central African Republic and Uganda.

At the highest latitudes, entire food webs may be disrupted by global warming. Vera Alexander, of the University of Alaska, has shown that near the poles, sea ice bends and concentrates the sun's oblique rays, promoting phytoplankton bloom beneath the edges of ice rafts. Most life in the polar oceans depends on this abundance of single-celled plant food. If the sea ice coverage is greatly reduced, the amount of food available to marine life will drop significantly.

How much the sea level will rise as the polar ice melts is debatable, but a rise of only a few feet would inundate large areas of coastal habitats, the crucial spawning grounds for many marine organisms. The Florida Everglades would lose many square miles with even a modest rise in sea level, threatening the national park which had the highest biodiversity in the United States when it was founded. (Within the last ten years, there has been an enormous drop in the number of bird species found in the Everglades.)

The world's greatest diversity of species lies in the tropics, where the warming will be minimal. The clearing and burning of tropical rain forests, however, remains the largest cause of species extinction. It also accounts for almost 25 percent of the carbon dioxide we are adding to the atmosphere. Slowing the rate of rain forest destruction would not only slow the onset of global warming but would also limit the loss of species, especially if areas particularly rich in species were saved.

With the threat of global warming on the horizon, biologists must add climate change to the list of other human disturbances that eat away at our planet's extraordinary diversity of life. Managing the reserves we have set aside to defend against the encroachment of humans is no longer enough. Now we must also anticipate how the changing climate might render the remaining wilderness unsuitable for many species.



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A colorful 20-million-year-old leaf is an elegant test of the theory of evolution

by Stephen Jay Gould

I had to go all the way to Moscow to complete my roster of fifty states—Moscow, Idaho, that is. My childhood was entirely northeastern. I wandered more in my twenties, hit the outposts of Hawaii and Alaska in my thirties, and filled in nearly all the blanks in my forties—Montana as forty-eighth, Mississippi as forty-ninth. But I had always missed Idaho, often by just a few miles (during visits to Yellowstone National Park, for example). So an invitation to complete fifty at age fifty could not be refused, and I gave a talk at the University of Idaho in Moscow a few months ago. While ruminating upon the symbolism of double fifty, I did fear that something terrible might happen once I crossed the state line after landing at the airport in Spokane, Washington. Perhaps God would ask me to intone Simeon's prayer, "Oh, Lord, now lettest thou thy servant depart in peace..." and then strike me dead. But I guess he doesn't care much about artificial boundaries on his bounteous real estate (or maybe he just isn't spending every moment watching over me). Frankly, westernmost Idaho looks just like immediately adjacent, easternmost Washington.

Moscow certainly sounds vestigially radical. They must have had some trouble during the McCarthyite hysteria of the 1950s. The local pizza joint is still called Karl Marks's. The town's name records only a distant Russian link. A local postmaster in the late nineteenth century had naming rights, and he so designated the town because the local topography reminded him of the terrain around a village--also named Moscow, and presumably for a Russian connection—back in his home state of Pennsylvania.

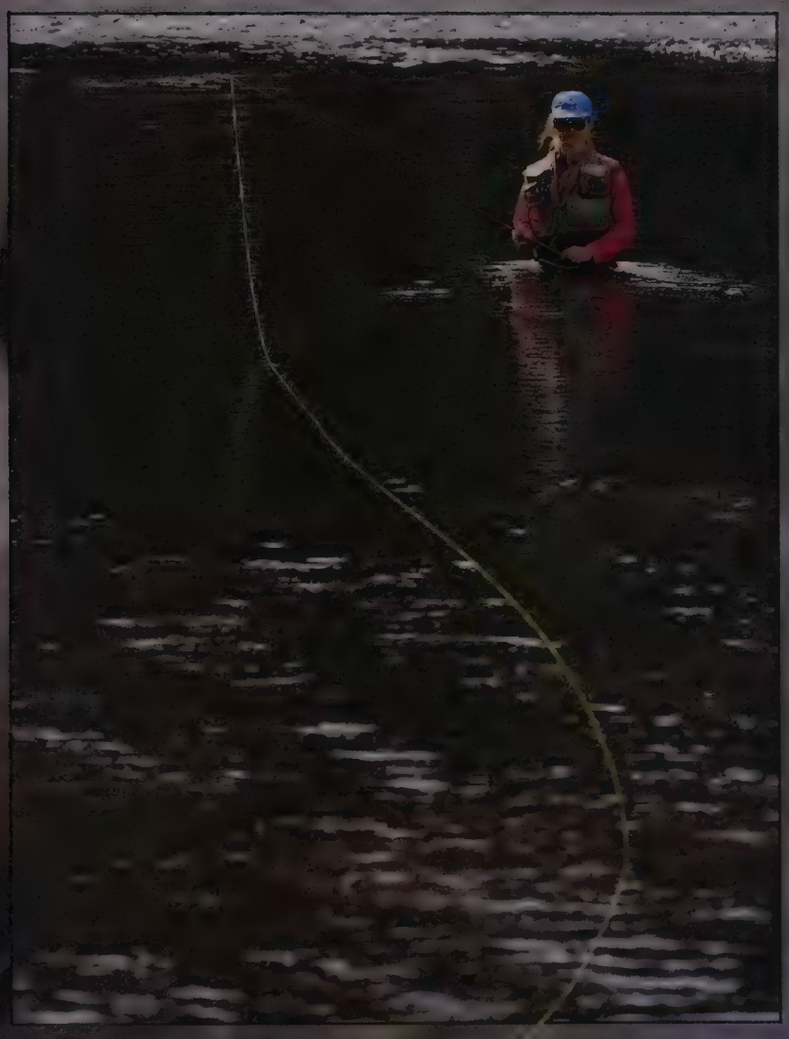
In fact, Moscow seems the very antithesis of dangerous and discordant foreign values. Could we possibly find anything more stereotypically apple-pie American than a town that advertises itself as the "dry pea and lentil capital" of America and has a "skyline" dominated by grain elevators at the railroad tracks? Summer noncredit courses at the university include "Bake a pie for the fair," "Pickle making for the fair," "Growing big pumpkins," and, for the truly risqué and adventurous, "Wine tasting in Spokane," the nearest city of any size.

From a loyal and lifelong eastern urbanite like myself, a New Yorker no less, such observations might elicit the most contemptible form of parochialism—the silly name-calling that elevates one's own insecurity to supposed superiority and precludes any understanding of different styles and terrains. I'll take a good bowl of lentil soup and a nice slice of pie at the country fair any day over much of the tedious, incomprehensible, and self-congratulatory debate that passes for profundity in urban intellectual centers. Moreover, we eastern urbanites from traditional elite universities have the actual situation backward when we imagine ourselves immersed in more stimulating discourse than our colleagues at isolated state colleges. In fact, few of us at Harvard talk much to our colleagues, especially those in fields even marginally distant from our own immediate work. We are all insanely busy with our own overcommitments, and we don't bother to set up any continuing network of intellectual discussion with local colleagues, if only because we sit upon a crossroads and compatriots from all over the world eventually come to us if we wait long enough.

But the faculty in Moscow, Idaho, must make everything happen locally. Visitors are not so frequent, and intellectual stimulation has to be indigenous. I have seen the same phenomenon in so many places off main routes. Lubbock in western Texas, for example, is perhaps the most isolated population center in America (the real Texas is as big as the legend, and Lubbock is actually closer to Denver than to Houston). I so admire my colleagues at Texas Tech University for the beehive of intellectual activity—seminars, discussion groups, reading circles, local performances—that they have established entirely by and with their own effort. I now extend this praise all the way to Moscow.

As another advantage offered by relatively isolated places, visitors receive a warm and welcome treatment. I once gave a supposedly prestigious lecture series at Yale. No one was mean to me (and the talks were well attended), but no one could figure out what to do with me either. Everyone was busy, and I visit New Haven for other reasons frequently enough anyway. So I gave the lectures, went right down to the railroad station and AMTRAK'd my way back to Boston. In Moscow, I just knew that folks were really happy to see me, and nothing makes a person feel better.

As one sign of hospitality, my host, Valerie Chamberlain, and other geologists took me on a field trip to their most precious local site (where "local" means a couple of hours of driving): the Miocene lake beds (17 to 22 million years old) exposed near the town of Clarkia. Western fieldwork conjures up images of struggle on horseback (or the minimal mount known as shank's mare)—toughing it out on one canteen a day as you labor up and down mountains. The value of a site is supposedly correlated with the difficulty of getting there. This, of course, is romantic drivel. Ease of access is no measure o



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importance: the famous La Brea tar pits are right in downtown Los Angeles. To reach the Clarkia lake beds, you turn off the main road at Buzzard's Roost Trophy Company and drive the remaining fifty yards right up to the site. Francis and Vickie Kienbaum, who own and run the company, gave their property a street address—Eighty-fifth and Plum because, as they explained, it is about eighty-five miles from Spokane "and plum out in the middle of nowhere."

Francis Kienbaum discovered the lake beds in 1971 when he was bulldozing his land to make a skimobile race track (now named the Fossil Bowl). The family business of trophy making began as a cost-cutting measure for supplying symbols of victory to winners at the track and then expanded to the usual roster of bowling clubs, Little League baseball, and so on. The Kienbaums still purchase the simulated metal (actually plastic) tops—the homunculi who bowl, bat, and race—but they manufacture the wooden bases on their wonderful collection of restored antique machining and carpentry tools. (I am always fascinated to meet people involved in businesses that most of us never think about, although they occupy an occasional corner of our lives. After all, I represent a profession—paleontology—that most people never think about at all. I once had a remarkable airplane conversation with a woman who sells department store mannequins—a larger and more serious business than you might imagine, complete with trade journals, juicy gossip, and a range of issues [high-priced lines for yuppie boutiques versus lower lines for K-Mart; colors and sizes geared to local differences].)

If the Kienbaums now make their living from the abundant wood in surrounding forests, their great discovery of 1971 extended our knowledge of local botany 20 million years back. Kienbaum, noting fossil leaves that peeled off the rock layers as black films and blew off in the wind, and recognizing the leaves as unrelated to any trees now living in the area, called the geology department in Moscow. Fortunately, Charles J. Smiley ("Jack" to his friends and colleagues), an expert paleobotanist, was on hand and able to take up the work. Jack Smiley has focused his research on the Clarkia site ever since and has enlisted an impressive and international array of experts to collaborate on the bounty.

Now fossil leaves from ancient lake beds are not rare (the site also contains a large array of microscopic forms and less abundant insects and fish). The fame and uniqueness of Clarkia rest upon the extraordinary preservation of the fossils. The shales are waterlogged and very finely bedded. Kienbaum, who greeted us on our visit, broke out large blocks with his bulldozer. I was handed several chunks and told to split the layers and look for leaves. I expected to grab a large chisel and geological hammer and bash away in the usual manner. Instead, I was handed an ordinary kitchen knife and told to slice parallel to the bedding as if the block were a giant seven-layer cake. I laughed with incredulity, for I don't believe in using ridiculously flimsy tools for hefty work (a legacy of a teen-aged month in France spent at a "work camp," euphemistically so called, trying to demolish some hypersturdy barracks, built to last a thousand years, with mallets).

Well, it looked like a big rock, but it sliced like butterscotch pudding. The rock split cleanly at bedding planes, revealing abundant leaves at each fracture. I now saw at first hand what has been amazing my colleagues for twenty years: the leaves look as fresh as the day they fell into the lake. They retain their original color, usually green, but often an autumnal red or brown. After just a few minutes of exposure and drying out, they oxidize before your eyes to a black film. This quick change in modern air makes us realize that the leaves hadn't been exposed to oxygen since their burial. They must have fallen into a stagnant lake, been rapidly covered in bottom sediments devoid of oxygen, and then remained buried (and waterlogged) for all 20 million years since.

The Clarkia lake formed when a lava flow blocked a stream valley, forming a narrow body of water, some twenty miles long and surrounded by forests. The lake gradually filled during its thousand or so years of existence, leaving a sedimentary sequence some ten feet thick. The composition of the flora clearly indicates much warmer climates then than now, for many of the trees are close relatives of forms now living in southern Appalachian swamps and uplands (bald cypress, tupelo, magnolia, for example). Interestingly, several of the Clarkia genera now live only in eastern Asia, indicating a previously wider range for these warm temperate forests, followed by later constriction as the earth cooled (and eventually went into a set of ice-age cycles), with some genera surviving only to the west in Asia and others re-

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maining in eastern areas of North America. Of Asiatic components in the Clarkia beds, the genus *Metasequoia,* the dawn redwood, has excited most interest—for this form was first discovered as a fossil and only later found living in a few remote valleys of central China.

Preservation with this degree of fidelity requires an unusual set of circumstances. (I can hardly describe the thrill and eerie feeling of splitting a 20-million-year-old rock and finding a leaf clothed in unaltered autumnal colors!) In this case, three happy circumstances conspired to present us with fossil leaves that look as fresh as the day they fell off their trees. First, many of the leaves blew directly into the lake; they were not altered and mashed up in long-distance transport. Second, the stagnant lake bottom contained no oxygen, hence no organisms to promote decay of the leaves. They were quickly buried and sealed in fine-grained sediments. Third, the rocks have remained unoxidized and water saturated ever since. When we split the rocks today, we expose the leaves to oxidation for the first time—and just a minute or two changes a glistening autumnal red into a dry black film, thus accomplishing in a moment what 20 million years didn't even begin.

Of course, Smiley and his colleagues noted the gorgeous and extraordinary preservation right away. They published several articles on details of cellular structure (including such organelles as nuclei and chloroplasts) retained by these ancient leaves, fruits, seeds, and stems. Other scientists then began to realize that if original form can be preserved in such fine detail, perhaps one might find some aspects of original chemistry as well. Karl Niklas, my brilliant paleobotanical colleague from Cornell University, then published several papers (with a number of co-workers) during the late 1970s and mid-1980s, reporting many remarkable details of "fossil chemistry," as unchanged by time and burial as the fine features of form.

These are the preludes to the latest chapter of Clarkia's fame, the first discovery that brought these wonderful fossils into an international and public spotlight (we professional paleontologists have delighted in them from the first)—the extraction and sequencing of DNA from chloroplasts of leaves in two genera, *Magnolia* and *Taxodium* (the bald cypress). (I have read all the major press reports of this discovery. They are generally accurate in describing the results but often misleading in not reporting the antecedents. One might think that the leaves were discovered yesterday, popped into a fancy machine in a modern molecular biology lab, and turned into a string of DNA base pairs. Science is continuity; science is lots of patience; scientists, following Edison's famous quip, perspire much more than they inspire. We never would have gotten to the DNA without Francis Kienbaum's bulldozer, Jack Smiley's unparalleled expertise in traditional systematics, and Karl Niklas's skills in chemical analysis. And the DNA sequence would mean very little without these equally important supporting data from other disciplines, most not so flashy and trendy as molecular biology.)

We have extracted DNA from ancient creatures before, but nothing that would inspire more than a "harumph" from a real paleontologist. Egyptian mummies, quaggas (zebra relatives that became extinct about a century ago), even frozen mammoths have yielded DNA. Before Clarkia the record went to a 13,000-year-old sloth. By moving from 13,000 to more than 13,000,000 we have extended the range of preservation for DNA more than a thousandfold. Such an enormous gain is bound to inspire some doubt amidst wonderment. Many biologists had previously thought that DNA could not survive without degradation for more than a few million years at most; consequently, some colleagues originally doubted the Clarkia results (although all, I think, are now satisfied). Only the extraordinary preservation of the Clarkia leaves—the main and repeated theme of this essay—has allowed this impossible dream to come true.

The first report, from Mike Clegg's lab at the University of California at Riverside, was published in the April 12, 1990, issue of *Nature* ("Chloroplast DNA sequence from a Miocene *Magnolia* species," by E. M. Golenberg et al., vol. 344, pp. 656–58). Golenberg and colleagues sequenced an 820 base-pair fragment of DNA from a chloroplast gene called *rbcL* in the Clarkia species *Magnolia latahensis*. (Most DNA resides on chromosomes in the nucleus. But the mitochondria, or "energy factories," and chloroplasts, or photosynthetic organelles, also contain small DNA programs.)

This discovery could not have been made ten years ago and is now only possible thanks to a revolutionary technique called PCR (polymerase chain reaction) which can isolate and amplify tiny amounts of DNA. Even with PCR, we might not have found any Clarkia DNA except for two happy features of chloro-

plasts. (No nuclear or mitochondrial DNA has yet been extracted from these leaves.) First, each cell contains many chloroplasts. Second, for reasons not well understood, chloroplasts preserve far better than any other cell organelle at Clarkia. (In a 1985 paper, K. J. Niklas, R. M. Brown, Jr., and R. Santos randomly sampled 2,300 cells from leaves in the Clarkia beds. They found that 90.1 percent contained chloroplasts, 26.0 percent mitochondria, and only 4.3 percent nuclei.) Thus, if any DNA is likely to be preserved, chloroplast genes are the obvious place to look.

In comparing this 820 base-pair sequence with the same region in a closely related living species, *Magnolia macrophylla,* Golenberg and colleagues found differences in only seventeen positions. The nature of these differences confirms a central fact about the evolution of DNA (not surprising, but always nice to have direct evidence from ancient DNA). Each position of a DNA string may contain any of four base pairs (called A, G, C, and T, for adenine, guanine, cytosine, and thymine). Each sequence of three base pairs codes for an amino acid (and a chain of amino acids makes a protein, the building block of organic matter). The DNA code is "redundant" in the third position—that is, a change in base pair in the last position of a triplet code does not alter the amino acid built from the triplet, whereas most changes in the first or second position do lead to a different amino acid. Base-pair changes that do not alter the amino acid are called silent substitutions because they don't change the chemical structure of the organism—and natural selection, working on organisms, will not notice them. Since natural selection regulates rates of evolution, and since the stability of good design is vastly more common than change, selection works to maintain existing arrangements almost all the time. Therefore, silent substitutions (which natural selection can't detect) should be far more common than those first and second position changes (called nonsynonymous) that yield a different amino acid, thereby altering the resulting protein. The *Magnolia* data provide a striking confirmation for this expectation. Of the seventeen substitutions between the fossil Clarkia magnolia DNA and the homologous sequence in a living species, thirteen are silent and only four change the amino acid involved.

The second study, published at the beginning of this year, offers more data and even more direct insight into evolution ("An *rbc*L sequence from a Miocene *Tax-*

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odium [bald cypress]," by P. S. Soltis, D. E. Soltis, and C. J. Smiley, *Proceedings of the National Academy of Sciences,* January 1992, pp. 449–51). Soltis and her colleagues sequenced a long 1,320 base-pair sequence of the same *rbc*L gene from chloroplasts of Clarkia bald cypress. (The entire gene has only 1,431 base pairs, so the fossil is most of totality, not a mere fragment.) They found only eleven base-pair changes between the fossil and the homologous sequence in modern *Taxodium distichum*—and all substitutions were silent third-position changes. Thus, the amino acid sequence for *rbc*L in bald cypress has been unchanged for 20 million years. Moreover, they compared this 1,320 base-pair sequence with a series of three other genera of increasing taxonomic and morphological distance, and they found a perfect correlation between total amount of DNA change and inferred evolutionary separation. For example, the dawn redwood *Metasequoia,* next in degree of resemblance, differs from fossil *Taxodium* by thirty-eight base-pair substitutions.

The difference in amount of change—less than one percent of base pairs in *Taxodium,* more than 2 percent in *Magnolia*—is intriguing. Perhaps *Magnolia* just evolves faster, but the two cases are not really comparable, and *Taxodium* may be more revealing. In *Magnolia,* the fossil and modern species are different. We are not certain that the modern species is the direct descendant, only one event of speciation removed from *Magnolia latahensis* at Clarkia. Perhaps several episodes of branching intervened; perhaps the two species are not parent and direct daughter on the evolutionary tree of *Magnolia.* Thus, the more than 2 percent difference records an uncertain evolutionary distance. But modern *Taxodium* may belong to the same species as the Clarkia leaves. In other words, in this case we may be looking at an unbroken and unbranched evolutionary sequence—a true continuity over 20 million years—and the smaller percentage of changes, with no alterations at all in amino acids, may record the actual architecture of evolutionary stability.

Extraction of fossil DNA will not make the traditional paleontology of overt fossils obsolete. First of all, to make the obvious (but not adequately appreciated) philosophical point, a DNA code and an organism are not the same thing. One is not more "basic" than the other or closer to the "essence of life," whatever that means. Organisms have DNA codes, and they have external forms and behaviors. Both are equal and fundamental components of being. DNA does not even build an organism directly, but must work through complex internal environments of embryological development and external environments of surrounding conditions. We will not know the core and essence of humanity when the human genome project is completed.

Second, to make the practical point, extraction of DNA from Clarkia leaves is a precious rarity, not the harbinger of a general revolution in practice. DNA quickly degrades in almost every situation where fossils are preserved; virtually no other known spot on earth can preserve such ancient DNA. Only the gorgeous and uniquely exquisite preservation of the Clarkia leaves permits the preservation of a molecule that most scientists once thought incapable of such long survival. Even at Clarkia, successful extraction of DNA is scarcely routine, but exceptional and difficult. Scientific papers traditionally do not report failures; you have to ask around to get the full picture. I did so and discovered that DNA extraction is no picnic or panacea. The great majority of fossil-leaf scrapings yield nothing, and the procedure is therefore long, expensive, and frustrating. (If extraction were easy, cheap, and routine, we would have seen a flood of papers, not just two reports—although several more will be forthcoming.) Moreover, only chloroplast DNA has so far been recovered, and chloroplasts preserve better than any other organelle at Clarkia. Unfortunately, nuclei are least stable, and most of the DNA resides there. We are not about to sequence the entire genetic program of a fossil magnolia.

Is the tale of Clarkia DNA then nothing but an isolated story in natural history, an episode with neither extension nor generality? Not at all, for this discovery of the most ancient DNA raises several deep issues in evolutionary theory—and at the most basic level that professionals rarely consider in their day-to-day work but that forms the heart of a series of essays for general readers. Above all, the sequencing of fossil DNA provides a striking illustration of the best kind of evidence that we can produce for the factuality of evolution itself.

Our creationist detractors charge that evolution is an unproved and unprovable bit of secular religion masquerading as science. They claim, above all, that evolution generates no predictions, never exposes itself to test, and therefore stands as dogma rather than disprovable science

"Go for the bronze, baby!"

Fleshy red coatings called arils surround the single seeds of the Pacific yew.
Steven C. Wilson; Entheos

held singly and enveloped by a fleshy mucilaginous covering called an aril.

Taxol was first extracted from the bark of the Pacific yew, *Taxus brevifolia.* Although other yew species contain taxol and traces of the substance are found in yew needles, Pacific yew bark continues to be the major source. Long considered a "trash tree" by the timber industry, the number of Pacific yews has been drastically reduced—perhaps halved—by clear-cutting, the logging practice that totally strips a targeted area. While bark suppliers are trying to recover as much of this logging slash as possible, the collection of such supplies from the wild is complicated by environmental considerations. Barring a breakthrough in synthesis, plantation culture of selected high-taxol clones of Pacific or other species of yew may offer a solution. Botanists and chemists are examining ways to maximize production, but first they must answer basic questions. Which species or cultivated variants of yew hold the most taxol? Is production seasonal? Why does the yew produce this molecule in the first place? Can we find ways to manipulate plants to increase their yield of the drug?

With these questions in mind, an expedition was mounted in the fall of 1990 to collect a rare species of yew in remote mountain regions of Mexico. Biochemist Melvin Shemluck and I had the good fortune to join forces with John Fairey and Carl Schoenfeld, two ardent plant explorers with three dozen trips to the region under their belts, and Eduardo Estrada, a botanist from the University of Nuevo León. Our destination, the Sierra Madre Oriental of northeastern Mexico, is a rugged series of peaks, ridges, and valleys. Rising to 12,000 feet above sea level, this mountain chain acts as a barrier to rain-bearing clouds blowing in from the Gulf of Mexico. The mountains channel the clouds as boulders channel a brook, steering them into valleys and canyons, allowing passage over lowlands or totally blocking the clouds' progress and creating a rain shadow on the far side of the range. This rain channeling, combined with varied soils and temperature regimes, has created a mosaic of mini-ecosystems. Within the Mexican states of Nuevo León and Tamaulipas, one can find alpine zones, cactus fields, pinyon pine forests, and lowland swamps. The land can change dramatically and rapidly from desert to forest in the space of a few miles.

Our quarry was one of the least-known yews, *Taxus globosa,* the Mexican yew. It ranges sporadically from northern Mexico as far south as El Salvador and Guatemala. We wanted to investigate this as yet uncultivated species to find out if its presence in lower latitudes might signal an amenability to warmer climates. If so, plantation culture may be practicable in countries where subsidized, commercial growth of yews could both supplant the production of narcotic plants, such as opium poppies and coca, and theoretically provide a source of now scarce taxol.

During our first day in the field, we drove to the summit of Cerro Potosi, a 12,000-foot peak capped with an alpine zone that is home to a rare Mexican dwarf pine. That night, we descended into Monterrey, a modern industrial city of three million, divided by a six-lane highway but

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The Mexican yew, one of eight species of Taxus, *grows in the Sierra Madre Oriental of Mexico.*
Rob Nicholson

ringed by dramatic mountain peaks. We rose early the next morning and began our trek to the yew area, passing by highway laborers warming their morning tortillas on a hubcap over an open flame. We turned off the main road and drove by pecan plantations and a road-drenching waterfall before heading up into the mountains.

The stand of yews we were searching for grew at the end of a long valley, some twenty miles away over snaking, cliff-hugging, rutted roads. Descending into the valley, we drove through a botanical paradise of black-stemmed oaks, their trunks festooned with bromeliads, ferns, mosses, and even epiphytic cactuses. Flowers of lantanas, ipomeas, and lobelias added splashes of vibrant color to the misty woods. We reached the bottom of the valley at the convergence of four rivers, which our Land Cruiser briskly forded. The next fifteen bone-jarring miles are reflected in our field notes taken en route, barely legible even to us.

As we left the oak-pine forest, a different set of woody elements took over, including mixed stands of redbud trees and dogwood, an association also common in the United States. A wood-plank shack with a tin roof completed the picture; I could have been in a hunting camp in the Appalachians.

We found our first Mexican yew at 4,400 feet. Melvin and I photographed and measured the object of our pilgrimage, relieved that we had found it at all. That day we began a process that we were to repeat with individual trees of as many different ages and from as many microclimates as possible in three populations of yews at least one hundred miles apart. We estimated the trees' ages and recorded their sizes and whether they were male or female. We also noted environmental conditions, including whether the plant was

growing in full sun or shade or was surviving under stress, such as grazing by cattle. We hope that some correlation might eventually come to light linking high taxol content with a physical or environmental factor. We collected a half pound of stems and leaves from each yew, then cataloged and attached numbered metal tags to the trees. We labeled the trees so that if a particular one was found on chemical analysis to be especially high in taxol and to warrant further collection, we would be able to find it again. (In my nightmares, these numbered labels are fashion items among the teen-age farm girls in the mountains.)

Finally, our vehicle could go no farther; we hit a long, steep incline of slippery red clay and were forced to park. After bracing against constant lurching, walking was therapeutic. As we climbed through the cool forest, we recognized many more temperate-zone plants. These mountains were apparently a flight path for flora migrating southward from both the east and west coasts of the continent. Maple, walnut, spruce, hop hornbeam, and witch hazel were driven south during climatic shifts in millennia past. We were seeing populations that persisted only in these isolated mountain pockets.

As we continued, more and more moist temperate species appeared, including roses, blueberries, hollies, and firs. At one point, the temperature abruptly cooled, the air became damp, and we were confronted with the unexpected vista of a dark forest of spruce and fir deep in the mountains of Mexico. This pocket of El Norte is only a mile long and half a mile wide and is nestled beneath a massive white-faced limestone cliff that must face rainstorms like a barricade. We found yews here as abundant understory trees tolerating dense shade. The foliage was a fresh lime green, with maximum needle lengths of a little more than an inch. Probably the most distinctive feature of the Mexican yew is its large fruit, with a globular cardinal red aril about the size of a chickpea. Most of the yews under these cliffs were less than thirty feet in height, with round canopies and often with multiple trunks. Farther south, however, we encountered more treelike specimens, some about sixty feet high with trunks one foot in diameter.

After two weeks, we headed back down the mountain trails with a heavy load of yew samples and seeds from a number of tree species for distribution to botanic gardens. Subsequent analysis of our yew by Susan Brobst, of the National Cancer Institute, showed a wide variability in the taxol content of our samples, some having ten times more of the molecule than others. While the average percentage of taxol in all our samples was good (in the mid-range as far as all *Taxus* go), a few trees were relatively rich in the drug. In the future, they may be collected and grown commercially in plantations or nurseries. Recently, some Mexican yews were taken to Peru to be incorporated into trial plots of narotic replacement crops.

While the struggle to increase the supply of taxol will continue for years to come, its discovery and development point to the logic of species preservation as a strategy fundamentally linked to our own preservation. The success of the yew as a medicine has finally freed it from the realm of myth and superstition and given it a new, scientific reputation as a healer.

Rob Nicholson studies rare plants at the Botanic Garden of Smith College in Northampton, Massachusetts.

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The Mysterious Origin of AIDS

Why did a virus of African wild monkeys take so long to infect us?

by Jared Diamond

How did the precursor of the AIDS virus pass from monkeys to humans if it's correct—as often assumed—that the precursor was a virus harmlessly infecting African wild monkeys? And why, after millions of years of coexistence between monkeys and humans in Africa, did AIDS emerge in us only recently? This article doesn't claim to solve these grimly interesting questions, because the solution isn't known yet. We're still groping for explanations, and AIDS research is a fast-moving field. Instead, I'll lay out the present status of the debate and a framework for understanding future developments.

As background, let's remind ourselves of the many ingenious mechanisms that microbes have evolved to spread from one host to another. Microbes may wait for their host to bite, or to be bitten or eaten by, a new host. They may cause sores on a host's body and then pass through the sores into a new host when it rubs against or has sex with the old host. Or they may make a host sneeze, cough, or have diarrhea, thereby spraying microbes into the air or the drinking water of a new host.

A disease will eventually disappear, at least locally or temporarily, if natural transmission of the responsible microbe is too inefficient (less than one new victim per old victim on average); or if transmission is interrupted by public health measures (as when cholera reached my city of Los Angeles earlier this year); or if everyone susceptible becomes infected and then either dies or recovers and becomes immune to reinfection (as used to happen during measles epidemics); or if the disease kills off the entire exposed population (as the incurable viral disease kuru, transmitted by cannibalism, was on the way to doing to the Foré tribe of New Guinea until cannibalism was suppressed).

With this brief crash course in disease transmission, let's now consider the origin of AIDS. There are at least two related sets of human viruses that probably infected and evolved in us independently. They're termed HIV-1 and HIV-2, where HIV stands for "human immunodeficiency virus." The less virulent HIV-2, virtually confined to coastal West Africa, is most nearly similar to a virus termed SIV_{sm}, which is widespread and harmless in wild sooty mangabey monkeys living in the same part of coastal West Africa where humans are affected by HIV-2. (SIV stands for "simian immunodeficiency virus," while "sm" stands for "sooty mangabey.") HIV-1, the virus responsible for the worldwide AIDS epidemic, reaches its highest frequency in people of central and East Africa. It is most similar to viruses occurring harmlessly in wild populations of various African primates, including African green monkeys, mandrills, and (rarely) chimpanzees.

AIDS was first recognized as a disease in 1981. However, the earliest-known AIDS-related human death, recognized in retrospect by molecular studies on stored blood samples, occurred in 1959. Given the odds against the preservation of samples from early AIDS victims, the first deaths probably occurred some time before 1959. The actual first infections may have preceded those first deaths by a decade, the typical interval between infection and death today. Most scientists believe that AIDS arose in central or East Africa, because that's where cases (as diagnosed in retrospect) first began to appear frequently, where the AIDS epidemic is now furthest advanced, and where the related simian viruses occur naturally.

We can't automatically assume that the AIDS virus spread from monkeys to us; perhaps it actually spread from us to monkeys. But that seems much less likely for several reasons. The benignness of SIVs in wild African monkeys, in contrast to the lethal outcome of HIV-1 infection in humans, suggests a much longer evolutionary coexistence between SIV and monkeys than between HIV-1 and humans. Another argument in support of a longer existence of the virus in monkeys is that their variety of SIVs is much greater than the variety of HIV-1s in humans. There are several plausible hypotheses for how the virus might have gotten from wild monkeys to humans. No one, however, has been able to suggest how it could have gotten from humans to wild monkeys.

The differences in molecular structure between SIVs and HIVs have been used to estimate how long ago the ancestral virus passed from monkeys to humans. Given the observed differences in structure of HIV-1 strains themselves that have arisen in recent decades, scientists usually quote the following estimates: HIV-2 arose from SIV_{sm} several decades ago; and HIV-1 arose from related SIVs earlier—perhaps a century or two ago, perhaps even a thousand years ago. Interesting as they are, though, those widely quoted estimates are based on some very uncertain assumptions. In addition, the estimates don't nec-

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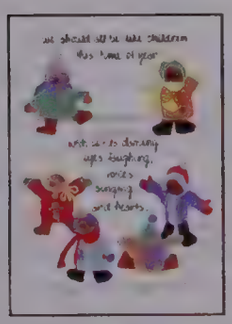

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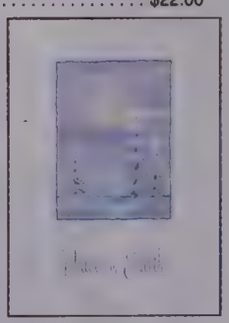

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essarily pinpoint the time of origin of AIDS as a disease. The estimates are based on HIV/SIV differences in *total* molecular structure. But the virulence of AIDS (contrasting with the benignness of SIV infection) might arise from only a tiny fraction of those structural differences. For example, a mutation in only a single nucleotide seems to have been crucial to the notorious virulence of the bacterium responsible for bubonic plague. Thus, even if an SIV infected humans a thousand years ago, and even if the accumulation of molecular differences between HIV-1 and SIV had already started then, the mutation that made HIV-1 virulent could still have occurred much more recently.

How did an SIV get from some African wild monkey into humans? In fact, there are dozens of precedents for a pathogen of animals being transmitted to humans and evolving into a specialized human pathogen. That's how many of our best-known infectious diseases, such as measles and smallpox, evolved. We're constantly picking up microbes from our pets, livestock, and wild animals by the usual means—getting bitten by an animal or having contact with its sores, blood, or feces. (For example, I'll bet that the children of some of you reading this piece have picked up cat scratch disease from your pet cat.)

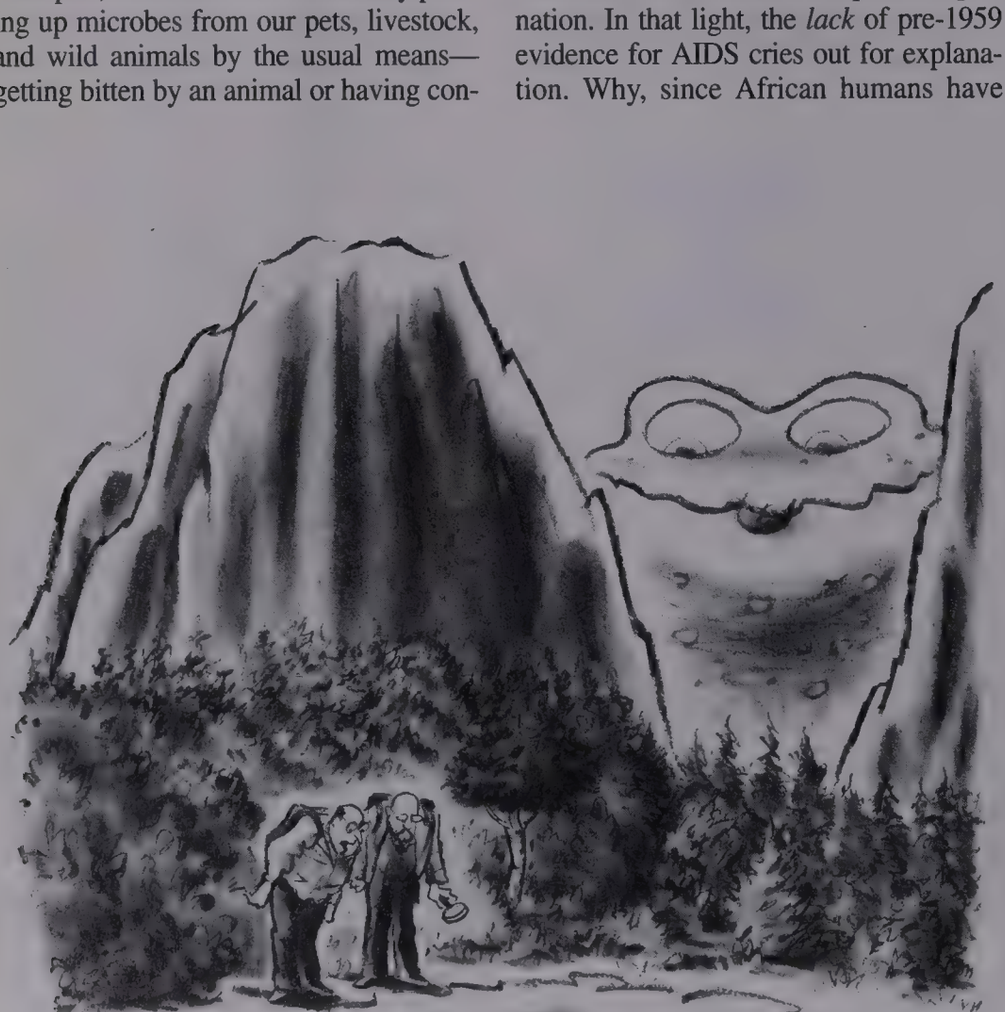
In particular, there's nothing surprising about our picking up SIVs, because many Africans hunt and eat wild monkeys and even keep young animals as pets. In the process, thousands of Africans must have gotten scratched or bitten by monkeys, gotten monkey blood on a skin wound while cutting up a dead monkey, or eaten undercooked monkey meat. Similarly, when Asian macaques kept in the same cage with sooty mangabeys picked up SIV_{sm}, the transmission presumably occurred by some prosaic mechanism rather than by cross-species sex. There is one recorded case of what seems to be SIV_{sm} itself in a West African farm worker, who presumably picked it up from a sooty mangabey in some equally prosaic way.

Thus, infection of humans with SIV over an extended period of time seems so inevitable as to demand no special explanation. In that light, the *lack* of pre-1959 evidence for AIDS cries out for explanation. Why, since African humans have been handling African monkeys for millions of years, was the origin of AIDS apparently so recent? That question seems to me the real mystery of AIDS origins. Three types of explanations, acting alone or in combination, suggest themselves.

According to theory 1, the recency of AIDS is just by chance. Perhaps virus transmission by handling a monkey is much more inefficient than transmission between humans. Perhaps SIVs themselves are as benign in us as in African wild monkeys, and perhaps the mutation making HIV virulent was a rare, unlikely mutation. In that case, the cross-species transmission or evolution of virulence occurred by coincidence for the first time within our own generation.

In support of that theory, one could point to many other new pathogens of humans that have arisen in modern times and either persisted or disappeared. For instance, O'nyong nyong fever was the name applied to an epidemic that exploded in northern Uganda in 1959. Caused by a mosquito-borne virus, it spread during the next two years to other areas of East Africa and infected 2 million people before disappearing as mysteriously as it had come. No one seeks reasons other than chance to explain the modern emergence of such diseases; why look any further for the origins of AIDS? But it strains one's credulity to dismiss as chance two independent and nearly simultaneous appearances of SIV-derived human pathogens, HIV-1 and HIV-2, within our own generation, after our millions of years of exposure to monkey blood.

In contrast, theory 2 accepts the reasoning that conditions adequate for infection of humans by African monkeys have existed for a long time. According to this theory, though, conditions for efficient spread of the resulting HIVs within and between human populations didn't exist until very recently. Local human populations in traditional rural Africa, or in the rest of the traditional rural world, may have been sedentary. Traditional societies may have imposed powerful injunctions against frequent changes of sex partners. Yes, people occasionally were infected by handling monkeys, but the resulting AIDS infection had little chance to spread before dying out. The few AIDS-related deaths would have been hardly noticeable against the background of frequent fatal infections in traditional societies. A man dies of pneumonia one year; perhaps his wife dies a few years later; perhaps another woman in the village also dies, and then her husband



"These pristine mountain lakes used to be swarming with frogs. None seem to have adapted to today's toxic environment!"

No one knows, though, that the second woman had had clandestine sex with the first man. Who sees any unique significance to those deaths, amidst all the other deaths and births in the village?

Only in recent times, according to this theory, did changed social conditions and technology in Africa permit one AIDS victim to infect dozens of others. The reasons seem obvious: the rise of cities, with professional prostitutes; men coming to cities to work, leaving their wives in the villages, and resorting to prostitutes; movements of people over long distances, due to civil wars in many countries; the rise of other venereal diseases, causing genital sores; and use and reuse of hypodermic syringes for medical care.

To many scientists, this is the most plausible theory to account for the recency of AIDS origins. To me this theory seems to assume a fictitious dream-view of placid, sedentary, traditional Africa until 1959. In reality, African history is full of civil unrest and movements ideal for the spread of AIDS. During World War I, hundreds of thousands of soldiers moved back and forth for four years across German East Africa and neighboring colonies, the current area of highest AIDS frequency in the world. In the early nineteenth century, the Mfecane (the migrations triggered by the rise of Zulu military power) drove millions of people thousands of miles over the area from Tanzania to South Africa. For many centuries until the 1800s, more than 10 million people were marched from Africa's interior to the coast and then exported as slaves by European and Arab traders. From late in the first millennium A.D. onward, military kingdoms dependent on cavalry fought over the same areas of West Africa infected today by HIV-2. Even earlier, the Bantu expansion swept out of West Africa to engulf almost the whole of sub-Saharan Africa. All those earlier uprooted peoples were no more likely to have been celibate and in perfect health than their modern equivalents. If AIDS existed at any of those times, how could it not have become widespread?

That difficulty leads directly to theory 3. Whereas theory 2 invoked new conditions for the spread of HIV between humans, theory 3 invokes new conditions for the spread of SIV from monkeys to humans. By far the most efficient means of transmitting the AIDS virus is by direct inoculation of virus-infected blood or tissue from one victim to another. Whatever the dangers of unprotected sex, transfusion of blood or blood products or tissue products remains far more dangerous. Only in modern times has the technology for such inoculation been routinely available. Could that technology itself have transferred SIV from monkeys to humans?

Attention has recently been drawn to several now-discontinued programs under which many humans did receive blood or tissue of African monkeys. In one program that began in 1922, malaria researchers injected blood of chimpanzees, occasionally of sooty mangabeys or other monkeys, into humans, in order to test whether primate malaria parasites could infect people. Published case reports document dozens of people injected directly with African primate blood in these experiments. Dozens of other people were injected with blood of people or Asian primates that had been injected with blood of African primates. Other such experiments may have been carried out but not published. If any of the chimps harbored SIVs, and if any of the mangabeys harbored SIV_{sm}, the precursors of HIV-1 and HIV-2, respectively, would almost certainly have been transferred to humans. A complication in linking such experiments to AIDS origins is that most of the experiments were performed in Europe and America,

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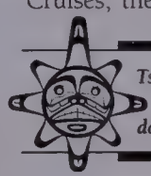

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but AIDS and HIV-2 infection apparently spread first in Africa.

A second program that transferred African primate tissues to humans also operated in the 1920s and 1930s. A theory was then current that normal aging in men is due to a decline in testicular secretions with age. If so, perhaps the progress of aging could be halted by grafting the testes of a young man onto an older man. (Pure testosterone would of course have been preferable to testis grafts, but testosterone had not yet been isolated.) Not surprisingly, few young men volunteered their testes to meet the consumer demand by the hundreds of older men clamoring to be recipients. Hence many grafts were instead taken from the testes of chimps or monkeys. If any of the donor animals were infected with SIVs, the viruses would almost surely have been transferred to the human graft recipients. The program wound down after 1935, when testosterone was isolated and shown to be without value in retarding aging. Again, a complication in attributing AIDS origins to these testis grafts is that the recipients were mostly Europeans or Americans rather than Africans.

Yet a third program was the preparation of an oral polio vaccine by growing weakened polio virus in cultures of monkey kidney cells. In 1957 and 1958 the vaccine was tested on several hundred thousand Africans in Zaïre, Rwanda, and Burundi. There is at least one precedent for infection of humans with an animal virus in the course of vaccine preparation: Marburg virus fever is the name applied to a disease that broke out in 1967 among workers at a vaccine manufacturing plant in Marburg (Germany), where African green monkeys were being used. However, there are many serious difficulties in proposing the 1957–58 polio vaccine trials as a route of SIV transmission to humans: for example, whether the kidneys came from African or Asian monkeys is unknown. In addition, the trials took place only one or two years before the first identified AIDS death, but the interval between known AIDS infection and death is about ten years. More generally, if molecular biologists are correct in their estimates of the time elapsed since HIV origins, the age of HIV-2 (several decades) fits with a theory based on modern medical technology, but the more uncertain estimate of the age of HIV-1 (a century to a millennium) does not.

Thus, all three theories to account for the apparent recency of AIDS—chance, new conditions for human-to-human transmission in Africa, and new technologies for monkey-to-human transmission—pose difficulties. If the theories addressed an insignificant problem, we could debate them dispassionately. The tragic importance of AIDS, however, charges the debate with strong emotions. Many Africans initially denied reports of AIDS' high frequency in Africa as racist slander, although those reports have now proved to be correct. Some Africans are still outraged at the conclusion that the AIDS virus arose from viruses (SIVs) of African monkeys and apes. Many biomedical researchers are outraged at hypotheses that transfers of SIVs to humans

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took place as a result of biomedical technology. In a few years, historians may cite our current theories as evidence of racism, neo-Ludditism, or antimedical hysteria. From our present perspective, it looks different. We acknowledge that we're groping for answers. All three competing theories are unproved and face serious objections but don't seem impossible. We just lack the foresight to know which (if any) of the theories will prove correct.

The future of AIDS is as uncertain as its past. Will humans become selected, through the deaths of some infected people and the survival of others, for genetic resistance to AIDS, as happened during the other great plagues of history (see my piece "A Pox upon Our Genes," *Natural History,* February 1990)? Will efforts to develop an AIDS vaccine succeed? Perhaps, but several decades of effort to develop a malaria vaccine have failed, and AIDS viruses have even more slippery antigens than do malaria plasmodia. Will efforts to develop anti-AIDS drugs succeed? Perhaps, but our track record for developing antiviral drugs is poor. Will AIDS remain incurable? Perhaps: medicine has had zero success at combating the slow virus responsible for kuru and some other viruses.

In fact, we already know enough to stop most transmission of AIDS viruses except that from mother to fetus. The rules include: practice safe sex and don't share intravenous needles. The main obstacles aren't inadequate technology or knowledge, but inadequate will. Government-sponsored campaigns of advertisements and education, and subsidy or free distribution of condoms, would help a lot. Of course one can object that such measures wouldn't stop AIDS transmission completely. But even if they decreased transmission by only 25 percent, they would be cost-effective, because each AIDS case is so expensive of money, medical care, and human potential.

The problem is that our governments, reflecting the will of many of our citizens, decline to support such measures, or even actively oppose them. This attitude is harder to excuse in politicians of countries (like our own) with a high standard of education than in politicians of developing countries. If AIDS does decimate the populations of many nations, it will have done so with our permission.

Jared Diamond studies evolutionary biology and teaches physiology at UCLA Medical School.

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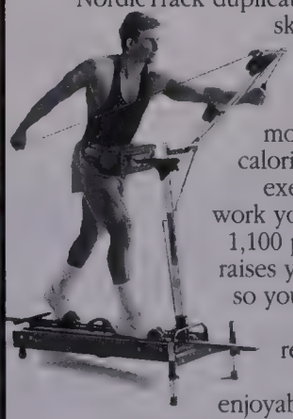

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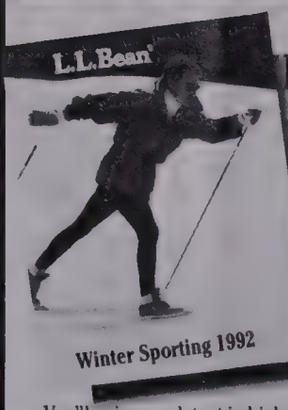

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Digging Beneath the Silk Road

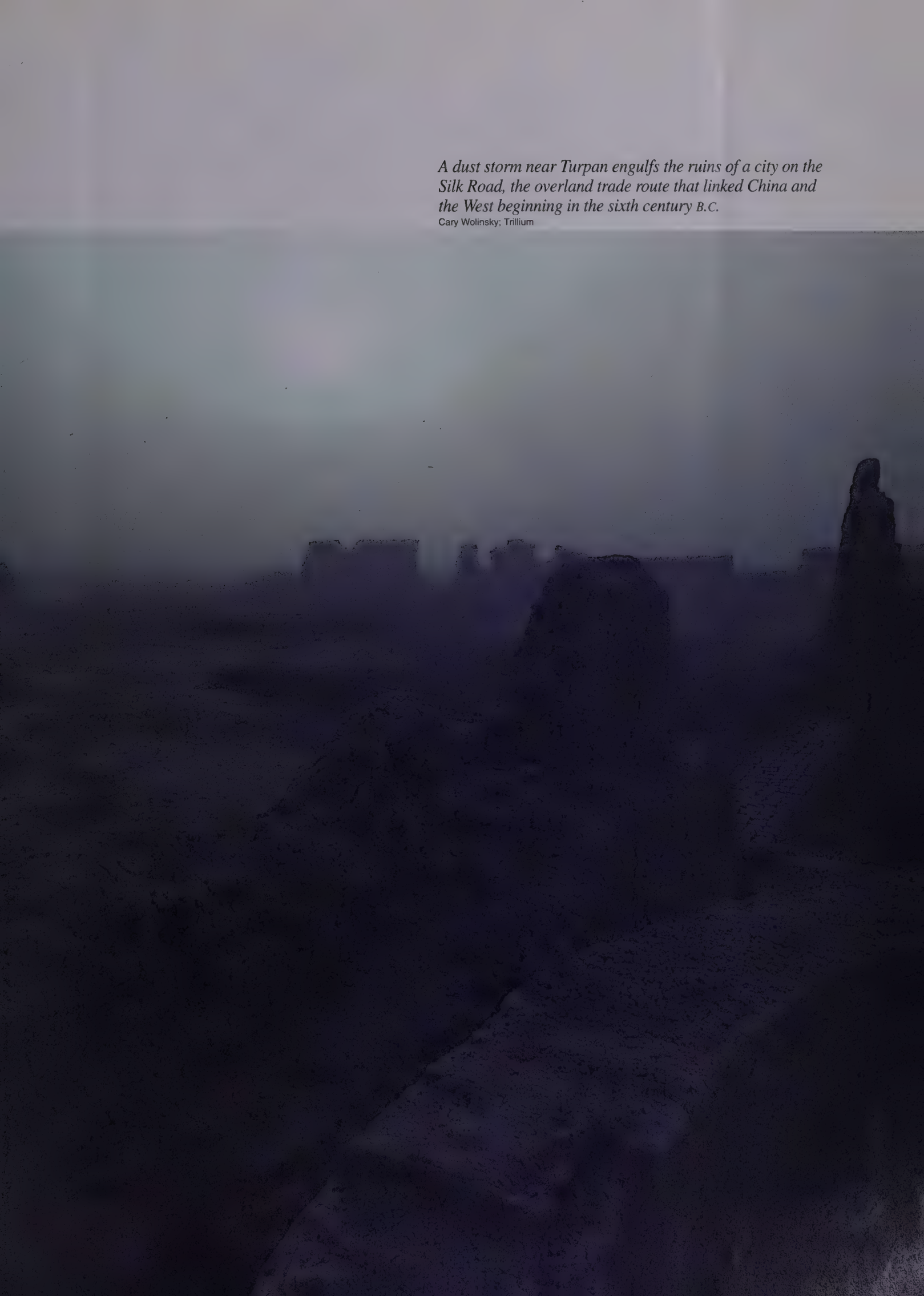
Do the sands of China's "sea of death" conceal the tracks of early humans?

by John W. Olsen

Arid plateaus, pebble-strewn plains, and desert basins seem unpromising places to look for signs of prehistoric humans. Yet earlier this century, major international expeditions, including those of Roy Chapman Andrews for the American Museum of Natural History, scoured the wastelands of Mongolia and western China for fossils, under the assumption that central Asia was the cradle of humanity. As far as early human fossils are concerned, these expeditions returned empty-handed. We now know that the earliest human ancestors lived in Africa, as long as three million years ago, while their descendants left no clear traces in Asia before about one million years ago.

But some of the world's best preserved specimens of our ancestor *Homo erectus,* which arose in Africa about 1.6 million years ago, have been found in East Asia. Among these are the remains of Peking man from Zhoukoudian in northern China, where cave deposits have yielded fossils of at least forty-five individuals, along with thousands of stone tools and other cultural debris. Other finds come from northern India and the western regions of central Asia, especially Uzbekistan. As uninviting as they seem today, the regions in between must have been traversed in ancient times, or even occupied.

Hoping to uncover some overlooked prehistory, I have been investigating the southern margins of the Tarim Basin, a 130,000-square-mile depression in China's Xinjiang Uygur Autonomous Region. The basin contains one of the most formidable arid areas on earth, the Taklimakan Desert. Larger than New Mexico, the Taklimakan figured prominently in China's dynastic history as a barrier to East-West communications. The great Silk Road, which once linked the Chinese and Roman empires, divided on the eastern edge of the basin, passed along its northern and southern margins, and joined again on the western periphery, near what is now the frontier between China and Kirghizstan. Many of the spring-fed oases that once served as caravansaries along the southern arm of the Silk Road have been



A dust storm near Turpan engulfs the ruins of a city on the Silk Road, the overland trade route that linked China and the West beginning in the sixth century B.C.

Cary Wolinsky; Trillium

Kirghiz riders, left, pass before sand dunes near the Pamir Mountains in western China. Map, below: The narrow piedmont region between the formidable Taklimakan Desert and the towering Kunlun Mountains may have been a hospitable pathway for early human ancestors migrating through Asia.
Joe LeMonnier

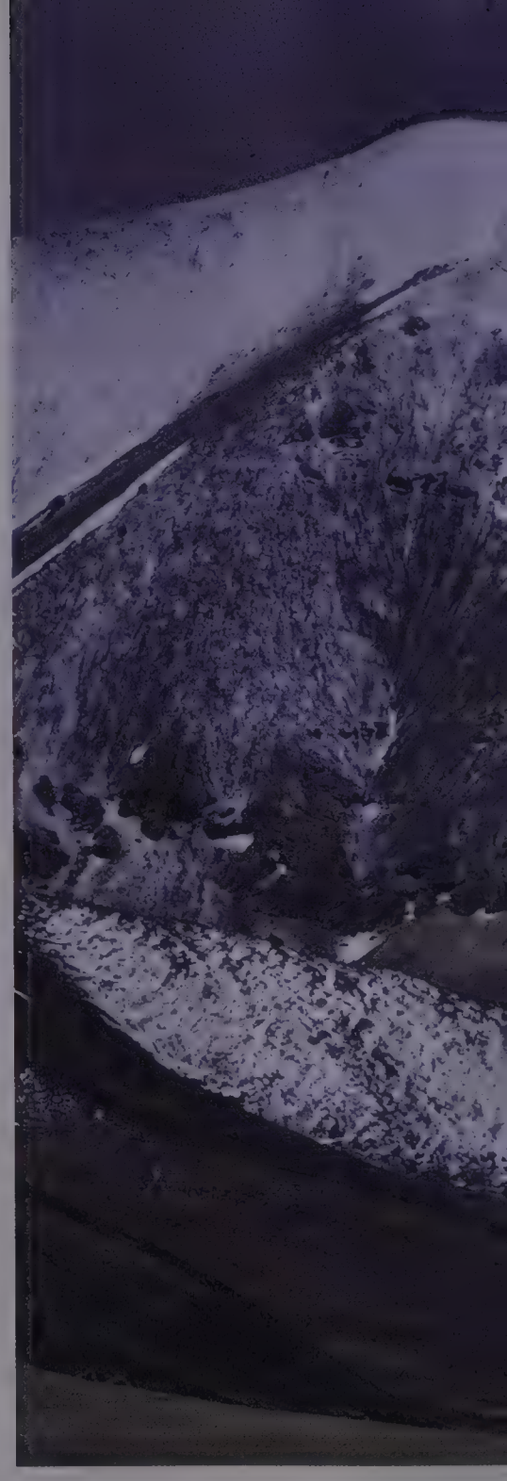
swallowed by the shifting sands, evidence that the desert has spread in historic times. Even the once-great trading center of Loulan, located just west of an ephemeral lake, Lop Nur, was apparently unable to support its burgeoning population when the lake became permanently dry, and was abandoned in the early fourth century A.D. When Marco Polo passed through his "ghoul-infested Desert of Lop" in 1224, Loulan had already lain beneath the sands for nearly a thousand years. Today China tests her nuclear weapons in this region.

Numerous archeologists have explored the southern Silk Road searching for artifacts from the early Chinese dynasties, the Han (206 B.C.–A.D. 220) through the Tang (A.D. 618–907). Beginning in the midnineteenth century, scholars from nearly every corner of Europe, America, and Japan flocked to northwest China to investigate claims of ruined cities and richly furnished burial grounds in the heart of the Taklimakan Desert. One after another, leading explorers of the day such as Przewalsky, Hedin, Stein, Pelliot, Otani, and Le Coq found peasants' reports of lost cities and cemeteries to be true, and all carried off vast quantities of Chinese relics to adorn the exhibit cases of their national museums. Since proper archeological procedures were not yet developed, let alone followed, this flurry of antiquarian inquiry destroyed many of the important clues that are uncovered during excavation; it also failed to yield any substantial evidence of the Tarim Basin's earliest populations.

The Taklimakan Desert proper—a nearly featureless expanse of sand with dunes up to 300 feet high—is uninhabited; a popular Chinese term for the area is *si-wang zhi hai,* or "sea of death." Early explorers often wrote in awed tones of the much-feared *kara-buran,* or "black storms," that engulfed whole caravans during some seasons of the year and were, in part, responsible for giving the Taklimakan Desert its evil reputation among travelers. Having experienced what I considered to be harsh sandstorms several times in the Sahara Desert, I was curious about the dreaded *kara-buran.* In 1987, my curiosity was more than satisfied. Late one afternoon as the wind began to pick up, my colleagues and I returned to a small village nearby to pass the night indoors rather than sleep out under the stars. In the wee hours of the morning we were awakened by a ferocious, howling wind. Switching on our flashlights, we found we could not see our hands before our faces. The room was filled with a mist of talcum-powder-like sand so dense that our flashlight beams resembled glowing solid bars. The dust was thick and choking; I finally fell asleep with a damp handkerchief tied across my nose and mouth to filter out the larger particles. When we awoke the next morning our room resembled an archeological dig itself—everything, including us in our sleep, had been covered by an inch or more of the Taklimakan's notorious sand. (We also learned that in October 1986, several dozen residents of southern Taklimakan oases were asphyxiated when a particularly violent *kara-buran* caught them far from any shelter.)

People do live along the Tarim River valley, which forms the northern border of the basin, and in the string of more than fifty oasis settlements found on the southern fringe of the sand sea. Today these

Jeffrey Alford; Asia Access



Ancient river deposits on the sides of the Niya River gorge, below, are a promising site for archeological exploration. The Kunlun Mountains, right, are the northern range of the Himalayas. Right, below: Goats graze near the northern margins of the Taklimakan Desert.

John W. Olsen

oases are occupied mainly by a Muslim Turkic nationality, the Uygur (*Taklimakan* itself comes from the Uygur word meaning "labyrinth"). Most scholars believe that the Uygur are comparatively recent arrivals, having settled in southern Xinjiang sometime after the ninth century A.D., when they fled Mongol domination on the central Asian steppes. These agriculturists grow fruit and grain in settlements ranging in size from a few families supported by a dozen acres of cultivated land to such huge aggregates as Hetian (Khotan) Oasis, which has a population of roughly 1.2 million.

To the south lies the Kunlun massif, the northern flank of the world's tallest range, the Himalayas. The peaks reach up to 23,000 feet above sea level, or 19,300 feet above the Taklimakan sand sea; they are called the mountains of darkness because they are largely shadowed when viewed from the north.

During our fieldwork in southern Xinjiang, we made a side trip into the foothills of the Kunlun Mountains to visit the small village of Chahar, not far from the Tibetan frontier. Sir Aurel Stein, a great British explorer, had passed through here in 1907 and had indicated the small cluster of mud-brick houses on his maps. Arriving in the village on market day, we were confronted by hundreds of curious Uygur farmers and their families, who called out, "Look! Foreign friends!" as we passed. In this realm where even Chinese people are an oddity and Beijing is a mythical city far to the east, we were not surprised to learn that we were the first foreigners of any nationality that most had seen. What did take us by surprise was an elderly man who remembered the day Aurel Stein and his party entered Chahar on horseback; he recounted to us how he, as a child of eight, had run after the horses, shouting and laughing, exactly as the village children had done on our arrival by Land Cruiser.

In between the mountains and the desert is a sloping, thirty-mile-wide gobi, or gravel-paved plain. This piedmont area, which serves as a watershed, is dissected by watercourses that flow north from their sources in Kunlun glaciers into the Tarim Basin. Only the Hetian River flows seasonally across the desert to join the Tarim River; all the other watercourses simply soak in and disappear beneath the Taklimakan's thick mantle of sand. The historic Silk Road cities—Dandanoilik, Niya, Karadong, Endere, and a host of others—were associated with major rivers, but thousands of smaller watercourses parallel them. Today many are inactive or carry water only seasonally. Apart from the spring-fed oases, these sites seem to represent the only places in the southern Tarim Basin where large groups of people could have lived in the past.

Although the cores of some of its deserts date back 65 million years, central Asia was relatively moist during much of the Pleistocene epoch, which lasted from roughly 1.8 million to about 12,000 years ago. During the extended periods of glaciation that characterized the Pleistocene, when snow cover and glacial packs of the Kunlun Mountains were heavier, the piedmont gobi must have supported richer plant and animal communities. Standing between the impassably high Kunlun peaks and the barren wastes of the Taklimakan, this area would have offered resources to human populations and acted as a natural conduit for hunter-gatherers traveling back and forth from the montane steppes of western central Asia to the hilly, deciduous forests of the Chinese interior. With this in mind I set out with a team of scientists in 1986 to survey the Kunlun piedmont and the adjacent desert, focusing on a sixty-mile-long segment between the Hetian and Cele oases.

Upon arriving, I decided the most practical way to learn about the Tarim Basin was to take a public bus that traveled along its margin. Even today, foreigners are still uncommon on public transportation outside the major tourist centers, but in 1986 my presence for the duration of what turned out to be a ten-day journey caused quite a stir. I was immediately adopted by several older women, who made sure I got enough fresh mulberries to eat from trees

along the roadside and paid the appropriate prices for noodles and mutton at each of our rest stops. One of my fondest memories of the journey is of sitting next to an old Uygur gentleman for days on end, neither of us speaking the other's language. Somehow I got across to him that I had come to southern Xinjiang to study "his" desert; thereafter, every few miles or so he would gently tap me on the shoulder and point out some unique desert feature—a falcon carrying off its prey, an unusual dune formation, the ruins of a former caravan station. When we finally arrived at his destination, a small desert outpost midway between Kashgar and Hetian, he hugged me and gave me his brass-sheathed dagger—the type for which the western Tarim Basin is renowned throughout central Asia.

Art Wolfe

Along with valuable information from local farmers familiar with the lay of the land, we used high-tech remote-sensing systems to identify the types of geological settings most likely to yield prehistoric sites. We pored over data from Landsat's multispectral scanners and thematic mapper and the space-shuttle-based large format camera. In addition, we made use of the shuttle-borne synthetic aperture radar (SAR), which had already enabled archeologists to peer for the first time beneath the surface of the Sahara Desert. Able to pick out features as little as 130 feet wide, SAR can expose ancient river channels and other geological features that lie beneath the sand. Such radar images currently exist for only the eastern margin of the Tarim Basin, but they have taught us what aboveground features to look for that

Nevada Wi

Nevada Wier

Uygurs make soup, left, in the butchery section of the large market held each Sunday near Kashgar. A vendor offers platters and kitchenware, left, below, in the city's daily market. Below: The interior of a Uygur home in Kashgar.

Galen Rowell; Mountain Light

are likely to be near buried extinct waterways and oases.

The complex winds in the Taklimakan, including the much-feared *kara-buran,* are also important agents in exposing archeological remains. Early explorers of southern Xinjiang recognized that cataclysmic storms often brought to light traces of early historical settlements. Space-borne remote sensing has proved extremely useful in identifying interdunal pockets, or "blowouts," where ancient land surfaces are exposed, often yielding archeological materials otherwise discoverable only by chance. Similarly, artifacts have turned up in the desiccated sediments of marshes and lakes dating from soon after the end of the Pleistocene. These sediments must have been covered up rapidly, otherwise the Tarim's fierce winds would have blown away the soil, leaving only a jumble of artifacts on the surface representing thousands, perhaps tens of thousands, of years of human history.

The 1986 survey enabled us to identify the most promising places in which to concentrate our future efforts. At the end of that expedition, we also found our first evidence of early prehistoric human occupation. In the midst of the towering dunes of the southern Taklimakan sand sea, we discovered a half dozen exposed gobi surfaces with archeological remains. These were simple, flaked quartzite tools, such as choppers and chopping tools—pebbles that have been irregularly chipped along one or two edges to produce a sinuous yet effective cutting edge. These sites, which consist of little more than scatters of stone tools, are difficult to interpret but may be the remains of temporary hunting camps.

Quartzite pebble choppers are not much to look at, but we were gratified to uncover them since they bore no resemblance to later Stone Age materials that have been found elsewhere in the southern Tarim Basin. The choppers were associated with geological strata dating to the last major cold snap of the Pleistocene, between 20,000 and 15,000 years ago, a time when some regions of the world became uninhabitable. So far these tools represent the earliest-known evidence of human populations in Chinese central Asia. (For a discussion of the possible significance of pebble tools in Asia, see "Bamboo and Human Evolution," *Natural History,* October 1989.)

In 1987 and 1990, I returned with geographer Richard W. Reeves and archeologist Sari Miller-Antonio, both colleagues from the University of Arizona; archeologist Huang Weiwen of the Chinese Academy of Sciences; and geologist Lei Jiaqiang of the Xinjiang Institute of Biology, Pedology, and Desert Studies. We set up a staging point in the Hetian Oasis in order to explore the south-central rim of the Tarim Basin, particularly the valleys of the Karakax (Black Jade), Yurungkax (White Jade), Cele, Keriya, and Niya rivers. We followed the courses of these principal rivers both north into the parched heart of the Taklimakan Desert and south to the point where they issued from the flanks of the Kunlun Mountains.

The gravel piedmont proved to be the most fruitful area for our search, since the

major rivers had cut deep canyons in some places, leaving a series of terraces, or remnant banks. The archeological remains found along these terraces can be assigned relative ages, enabling us to determine whether they are from Pleistocene times or more recent. Simple chipped-stone choppers and chunks of quartzite used as a source of raw material also turned up near smaller waterways, many of which are now extinct but which once flowed at least seasonally.

Other sites lay on the middle reaches of the Keriya and Niya rivers. These consisted of surface scatters of stone tools, sometimes accompanied by shallowly buried scrapers, choppers, and other chipped-stone artifacts of the same age. In several cases, artificial alignments of rocks and boulders appeared to be the surviving foundations of simple lean-to huts and animal-hide shelters. Located on ancient river banks, such sites reflect a time when the Tarim Basin's resources were abundant and game flourished along the margins of these now-dry stream beds.

The surface finds and excavated materials demonstrated at least two periods of prehistoric human occupation in the southern Taklimakan. One, which we correlate with the last glacial maximum, dates to between 20,000 and 15,000 years ago and is characterized by choppers and chopping tools made from pebbles and other simply chipped scraping tools made from large flakes. These artifacts were probably made by nomadic hunting-and-gathering people to kill and butcher game and to collect and process wild vegetables.

The other prehistoric tradition we are able to identify belongs to a period of optimal climate, from about 7,000 to 4,000 years ago. The artifacts are dominated by microliths (exceptionally small stone tools) but include fine red, sand-tempered pottery; both are clues to a relatively recent age. Pottery is one of the defining traits of the Neolithic period, or New Stone Age, beginning about 10,000 years ago, when human groups became more settled and began to cultivate food. The pottery remains may thus indicate the beginnings of food production in central Asia. Microliths are generally associated with hunters, however, suggesting that if these were farmers they nevertheless continued to supplement their diet with game and probably wild plants, perhaps on a seasonal basis.

In contrast to the nomadic or seminomadic Pleistocene hunters, these later people may have lived most of the year in settled homesteads, even villages. Since our finds do not include substantial house foundations or cemetery sites, they may only represent seasonal camps. Possibly the inhabitants gathered in larger settlements during part of the year but dispersed at other times, according to the local availability of water and of wild resources such as migrating herds of game.

So far we have no proof of a human presence before 20,000 years ago. In addition, our archeological record has two gaps. One, from 15,000 to 7,000 years ago, came between the Pleistocene hunter-gatherers and the makers of microliths and pottery. Another gap followed the disappearance of the microlithic tools about 4,000 years ago and the florescence of the Silk Road trading centers, such as those represented by the first century B.C. ruins in the oases of Hetian, Yutian, and Minfeng. The possibility remains that further fieldwork will help fill these gaps, but since we surveyed many kinds of places where artifacts could have been preserved, we believe the southern Tarim Basin was probably used little or even abandoned during these times.

Climatic changes may be partly to blame. During the late Pleistocene, for example, environmental conditions fluctuated greatly, and at times essential resources, notably water, may have become scarce. Given the localized nature of the Taklimakan's resources and the sensitivity of arid lands in general to human overexploitation, even a sparse population of hunter-gatherers could then have helped make the area inhospitable. We suspect that, first, the early nomadic hunter-gatherers overhunted the game, making the area unattractive for those depending on

A camel's back, right, provides secure passage for a Uygur family in the Pamir Mountains. Below: A Uygur shepherd and his daughter at the family's permanent winter quarters.

Nevada Wier

that resource. Later on, people equipped with some knowledge of food production could have found the region more hospitable. But they too may have exhausted local resources and been forced to move elsewhere.

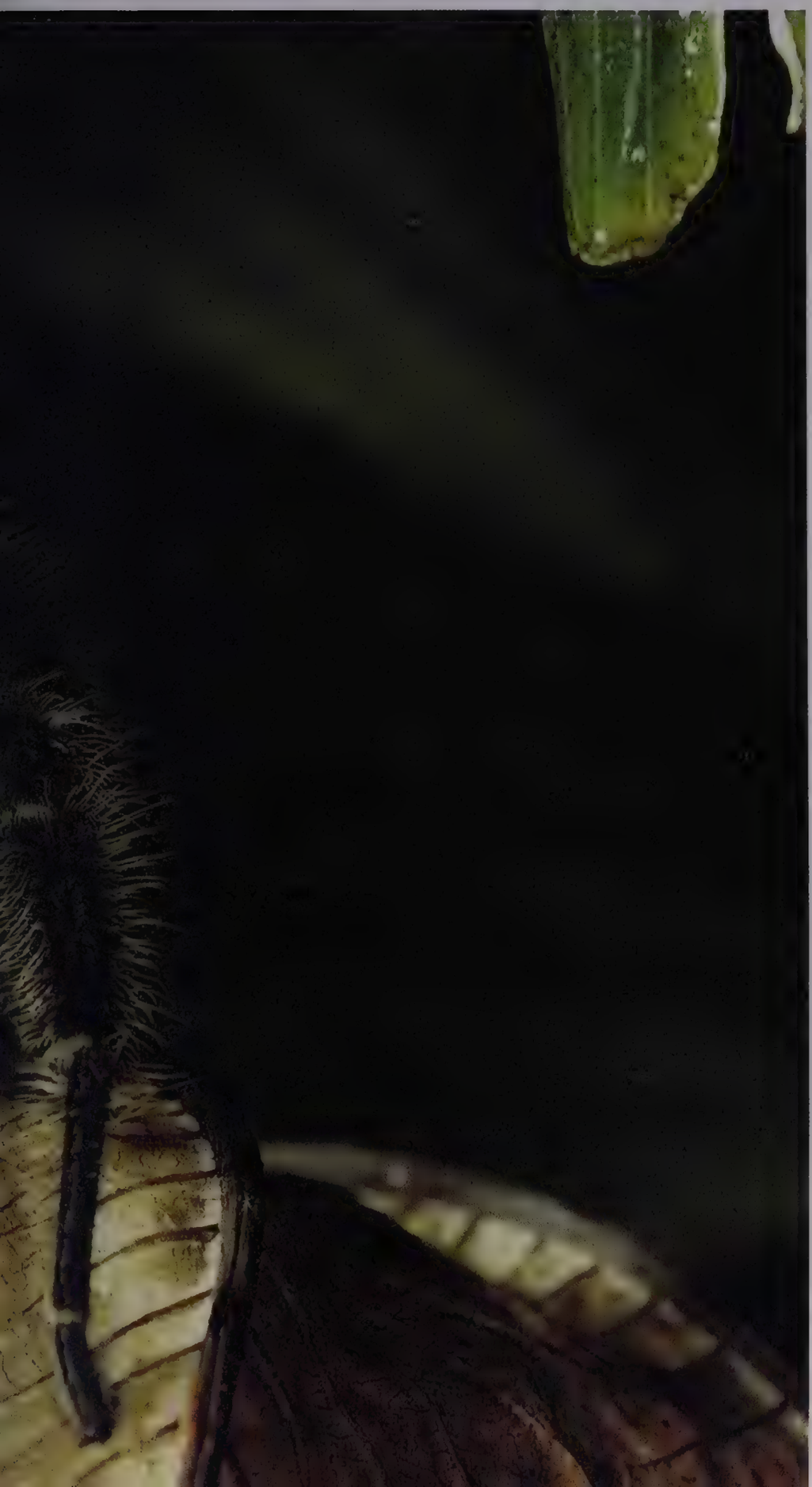
A central purpose of our research is to clarify the mechanisms of desertification in this region. Chinese historical sources, including travelers' diaries and the manifests of provisions stocked by Chinese garrisons, and the corresponding archeological record suggest that a combination of climatic deterioration and agrarian mismanagement in the historical period contributed to creating the impoverished environment we see today. These observations are helpful to us in trying to understand the more distant past. At the same time, we hope our research will prove of some practical benefit. Many of the oasis settlements of the southern Taklimakan Desert have grown explosively in the past half century—in some cases the populations of small settlements have more than quadrupled. In making decisions about the Tarim Basin's future development, China's planners may want to review both the successes and failures of the region's long-forgotten prehistoric peoples. □

Tarantulas lie in wait for their prey, insects and even small vertebrates, but they themselves may become victims of larger animals. When threatened, this tarantula, found in Venezuela, raises its front legs to appear more fearsome.
Stephen Dalton; Oxford Scientific Films

The Importance of Being Hairy

Instead of using their fangs, many tarantulas rely on their fuzzy coats for defense

by Samuel D. Marshall



As I worked my way up a thickly forested hillside in the Kaw Mountains of French Guiana, horseflies swarmed around my head. The afternoon was hot and humid, and despite the shade cast by the tall trees, I was dripping with sweat. My eyes were focused on the ground, which I searched thoroughly, looking alongside each rock, root, and fallen branch for tarantula burrows. A short while earlier, I had found a burrow concealing a *Theraphosa leblondi*. (*T. leblondi,* the only species in the genus, is the world's largest spider. It weighs in at almost a quarter of a pound and has a leg span of ten inches.) Knowing that the burrows of these tarantulas are usually found in clusters, I intensified my search. Finally, I turned up a second burrow about nine feet from the first. The entrance, which was almost completely obscured by fallen leaves, was covered with a fine mesh of silk, and hiding within was a female spider guarding her egg sac. When I dug up the burrow, the spider, clutching her egg sac in her fangs, reared up and produced a hissing noise. Despite the spider's warning, I continued to excavate the burrow. She responded by brushing a rear leg rapidly downward across the rear of her abdomen, releasing a small cloud of shed hairs. Suddenly, my hands and throat were burning and itching furiously, a sensation that persisted for several days.

The memorable hissing sound and the irritating hairs give these tarantulas an effective two-stage defense analogous to a rattlesnake's rattle and bite. Such large spiders would make a good meal for animals, such as coatimundis and peccaries, that root in the soil for food. But after receiving a snootful of tarantula hairs, these predators learn to avoid spiders that give a warning hiss.

Tarantulas do bite in defense, but usually only as a last resort. And despite their dark reputation, none can inject a venom that is fatal to humans, although some species possess venom capable of killing rodents. (The force alone of a *Theraphosa* bite is sufficient to kill mice, which the spiders will almost always strike in the

head or neck.) To deter vertebrate predators, however, many New World species use a more subtle defense mechanism—their hairs. Although many plants, such as stinging nettles, are equipped with "hairs" that produce hives, among animals such hairs are found only on tarantulas and the larvae and adults of some moths. While the unpleasant effects of moth hairs may be caused by a chemical coating, as well as their structure, tarantula hairs produce itching and swelling with their structure alone: each hair is covered with hundreds of tiny barbs and has a sharp, penetrating tip. As the hairs work their way into the skin of the victim, the barbs can trigger a severe reaction.

The unpleasant effects of tarantula hairs have long been known to people that keep the spiders for research, but the phenomenon was not studied in detail until the early 1970s, when John Cooke, an associate curator in the American Museum's entomology department, Vincent Roth, then director of the Museum's research station in Arizona, and Frederick Miller, a medical doctor at Nassau County Medical Center, examined preserved tarantulas in the Museum's collections. They found four different types of defensive hairs in the New

Samuel D. Marshall

Newly hatched tarantulas of the species Theraphosa leblondi, *the largest spider in the world, are dwarfed by their mother, left. Amid the litter of a Peruvian rain forest, below, a disturbed tarantula rubs a hind leg against its abdomen to shed irritating hairs in defense.*

Rick C. West

World species, but none at all in the Old World tarantulas. Work with live tarantulas revealed that the effects of these hairs could be quite specific. For instance, hairs found in tarantulas from Arizona appear to be specially adapted to inflame the nasal passages of grasshopper mice (which feed on invertebrates, such as spiders), with fatal results. These same hairs have a negligible effect on the skin of humans.

Spiders on the whole are hairy. Their hairs serve so many functions that the term *hair,* with all its mammalian associations, is misleading. More properly called setae, the hairs are part of the spider's cuticle, and many are actually organs of touch, taste, and hearing used for sensing the climate, finding food and mates, and detecting predators. Only in tarantulas, however, have hairs been modified for defense.

The hissing sound produced by *Theraphosa* is not unique; other spiders make similar noises when threatened, but this tarantula's hiss is the loudest. Scientists assumed that *Theraphosa* produced the sound the same way other tarantulas did, by rubbing together opposing spines near the bases of their front legs. In the 1980s, however, George Uetz, an arachnologist at the University of Cincinnati, Ellen Thoms, then an entomologist at the Cincinnati Zoo's Insect World exhibit, and I discovered that *Theraphosa* produces sound in an entirely different way. The outer surfaces of its pedipalps (the appendages next to the mouthparts) and the opposing surfaces of the first two pairs of legs are covered with hairs that resemble bottle brushes. When threatened, the spider rears up in a typical tarantula display. It then draws the opposing surfaces of the first two pairs of legs against each other and the outer surface of the pedipalps, producing a hissing sound that is similar to white noise and can be clearly heard several yards away.

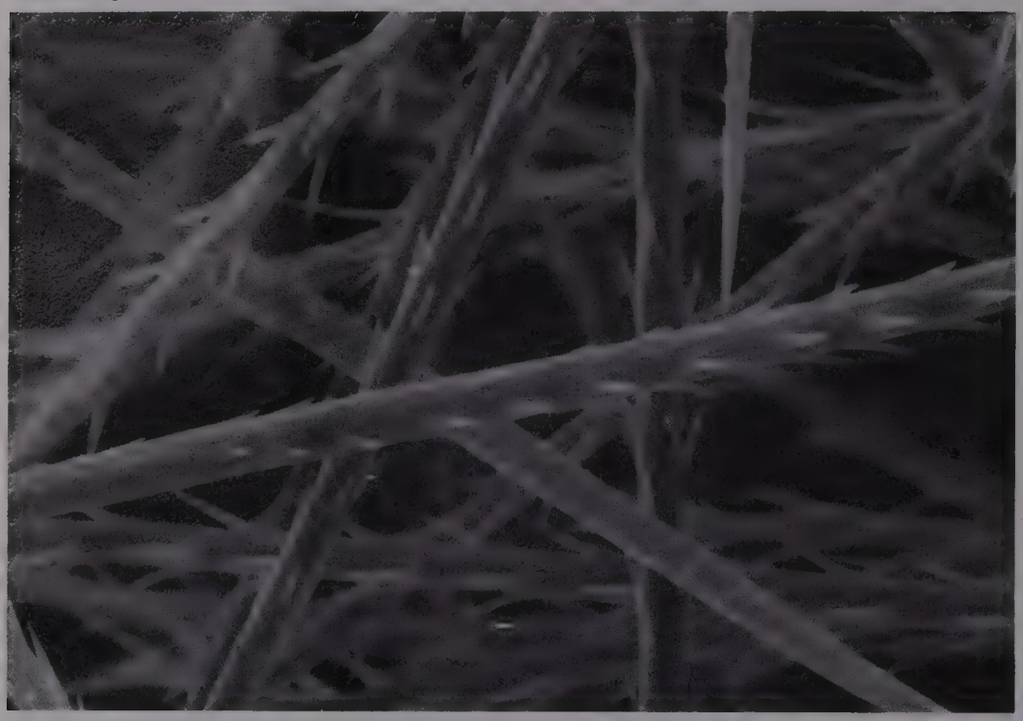
To show that these hairs, not the previously described spines, were indeed the source of the sound, we anesthetized several spiders and shaved their legs. This effectively silenced their display. While the brushlike base of the hairs can be seen with the naked eye, only scanning electron microscopy reveals that they also have a toothed area at the end. The sound is produced as the teeth on the hairs of one leg are combed through the brushes on the hairs of the opposite leg.

In addition to warning off vertebrate predators, *Theraphosa* must also defend itself against parasites. When I collected the spiders in French Guiana, I noted that many had small gray flies on their bodies. The flies had emerged from pupal cases, which looked much like grains of brown rice and which were attached to the top of the central portion of the spiders' bodies. The flies feed on the remains of prey and other material in the spider's burrow but stay near the host, safe from retaliation because of their diminutive size. These flies turned out to belong to a previously unde-

Samuel D. Marshall

Hairs (magnified 1,200 times) from the abdomen of Theraphosa, *below, bristle with the barbs that cause burning and itching upon contact with skin. The barbed hairs (magnified 525 times) of another tarantula, right, show a different design, but their effects are similarly unpleasant.*

Leslie Manning

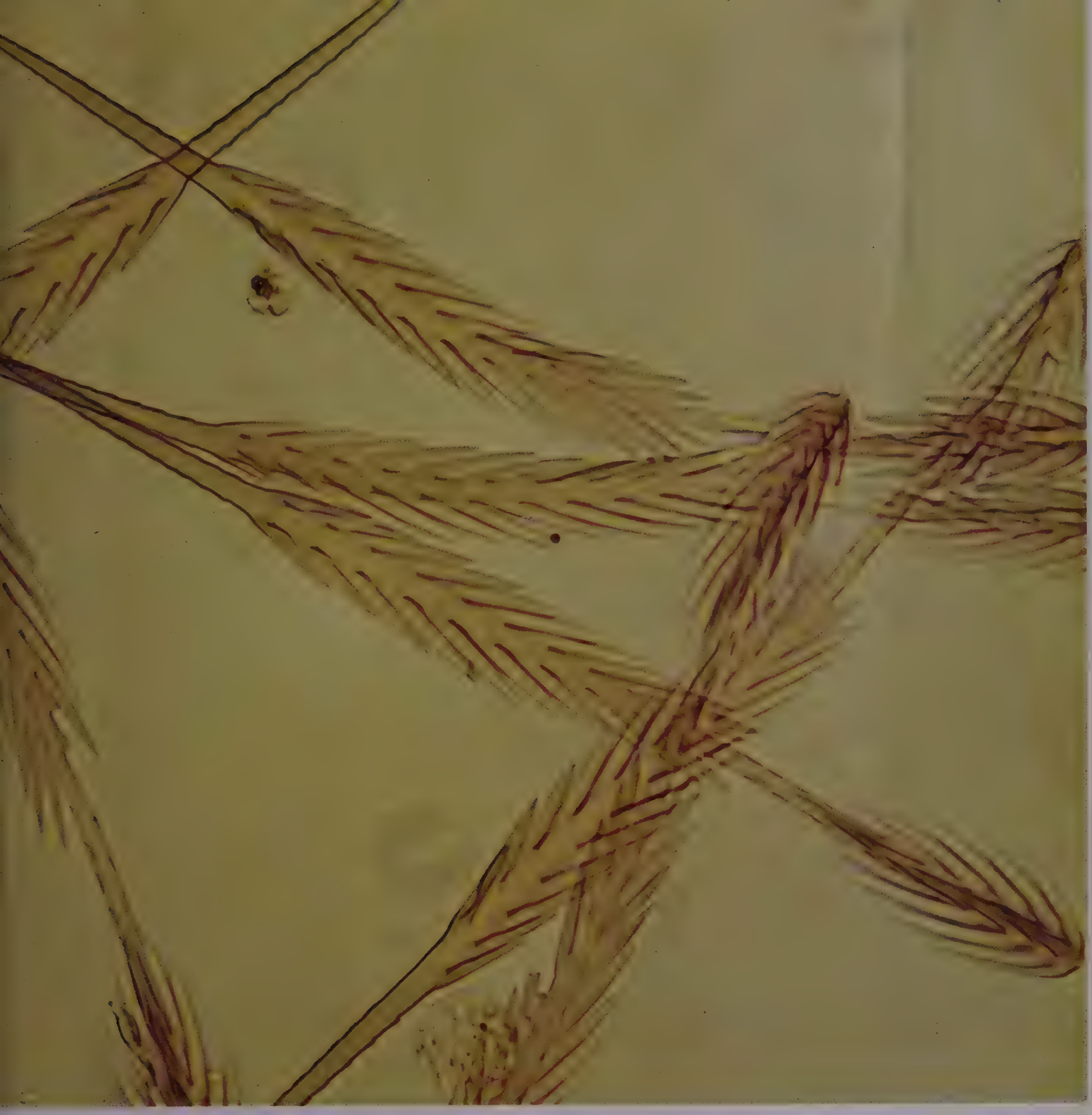


scribed species of scuttle fly (in the genus *Megaselia*), found only in association with *Theraphosa*.

I also saw the larvae of this fly crawling around the bases of the spiders' legs, where they appeared to be feeding on the spiders' blood. Laboratory observations led me to wonder if the defensive hairs might help *Theraphosa* rid itself of these unwelcome parasites during the critical period just after the molt when it is essentially defenseless. Hours before it sheds its skin in its burrow, *Theraphosa,* like other tarantulas, lays down a silk mat approximately equal in circumference to its leg span. But immediately before molting, the spider also brushes hairs off the sides and end of its abdomen, so that the silk mat becomes covered with hair. I conducted a few tests to see if the larvae of *Megaselia scalaris* (a closely related scavenging fly commonly found in the United States) might have more difficulty crawling on the hair-laden silk mats than on the hairless silk mats of other tarantula species. I placed fly larvae on both types of mats; most eventually stopped crawling, but the maggots on the hairy material stopped much sooner. When I observed the larvae under magnification, the cause was obvious: on the hairless mats, the setae of the larvae (used for locomotion) had become entangled in stray strands of silk, while on the *Theraphosa* mats, the larvae were writhing around, completely wrapped up in the long, barbed hairs. Presumably, the entrapped larvae would not be able to transfer to a newly molted spider.

Theraphosa also incorporates defensive hairs into the white silk of its egg sac. The female lays down silk in a circular mat and strokes the sides of her abdomen with her last pair of feet, knocking off the hair, until she has built several layers of hair and silk. The resultant material is so hairy that it resembles coffee-colored terry cloth. She then deposits her eggs on the mat and gathers up the edges to form a sac. This explained the curious balding patterns that I noticed on female spiders I had collected. Tarantulas will often denude the rear end of their abdomen when shedding defensive hairs; indeed, captive spiders are often bald there from being disturbed too often. (Lost hairs are replaced when the spider molts and gets a new skin.) The *Theraphosa* females, however, were often bald on the sides of their abdomen.

Parasitic flies attack spider eggs as well as adults. To see whether the hairs protect the eggs from the depredations of a generalized scavenger such as *M. scalaris,* I compared the hairy egg sac material used by *Theraphosa* with the egg sac material used by red-knee tarantulas, a species that does not incorporate hairs into its silk. I put bait (dead crickets) into glass vials and covered some of the openings with egg sac materials and others with mesh. I found that the two kinds of egg sac material were equally effective at excluding scuttle fly larvae, while the mesh covering did not prevent the maggots from getting inside. While the test revealed that the hairy material offered no additional protection, I suspect it may camouflage the egg sac from more specialized predators that use olfactory cues to distinguish the eggs from the mother.



During four trips to French Guiana, I collected eight tarantula species in five genera. After *Theraphosa,* the best-known tarantula in French Guiana is *Avicularia,* referred to locally as the *matoutou.* It is the garden-variety tarantula, found in a wide range of locations. This spider seems to benefit from human activities, building its silken retreat under the eaves of houses, as well as in cultivated crops, such as banana trees and pineapple plants. The only place in the wild I've seen it is in trees on the coastal savanna. The *matoutou* also has abdominal hairs that cause itching, but they differ in structure and use from those of *Theraphosa* and others. These are the only defensive hairs that are attached to the spider by short stalks, with the sharp, penetrating end directed inward toward the skin. When handled, the spider is very docile and does not rear up and brush the hairs off with its hind legs; instead, it brushes its abdomen against you, detaching hundreds of tiny harpoons from their stalks. The movements are slow and casual, hardly what we expect defensive movements to be, but there is nothing casual about the itching that follows.

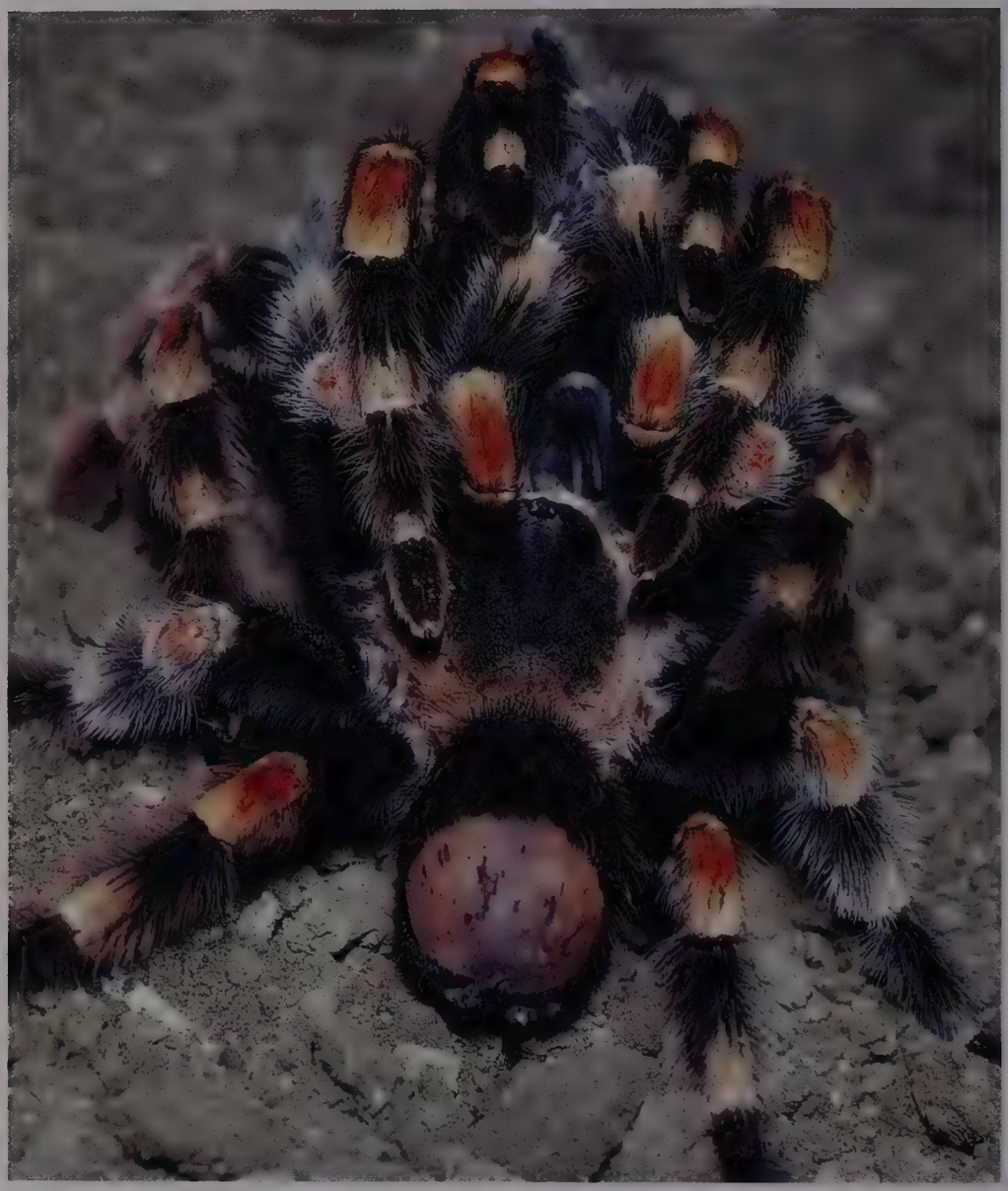
Tarantulas without defensive hairs seem to compensate for this lack of protection with aggression. Related to the *matoutou* is a tarantula of the genus *Tapinauchenius,* which also lives in silken retreats in trees. It lacks defensive hairs but is very aggressive and bites with little provocation. This same comparison may be drawn between the Old and New World tarantulas. In my experience, African and Asian tarantulas are surprisingly aggressive compared with most of the tarantulas from the New World. I have even heard a story of an Old World tarantula that reared up, threatened, and then chased a dog that was disturbing it.

I discovered that tarantulas in the genus *Ephebopus,* also found in French Guiana, bear defensive hairs on their mouthparts, instead of on their abdomen. These tarantulas live in burrows in the forest and along road banks. One especially attractive species, with canary yellow stripes

Anthony Bannister; NHPA

A pair of Mexican red-knee tarantulas mate, below. The completely bald patch on the abdomen of the spider in the foreground is typical of many captive tarantulas; overhandling causes them to shed all their defensive hairs. A monkey spider from southern Africa, right, rears up in an aggressive threat display common to Old World tarantulas.

Bill Ivy



running down its jet black legs, is fairly aggressive. When threatened, it brings its pedipalps down across the base of its fangs in a scrubbing motion, releasing a cloud of hairs. When I looked at the inside surface of a pedipalp, I saw a gold-colored brush of hairs, which readily detach. When I applied these hairs to my forearm, there was no reaction; but when I exposed mice to the hairs, they began to groom and scratch furiously.

Over evolutionary time, a multitude of uses can often be found for preexisting physical structures. Bird beaks are a familiar example. They have evolved into specialized tools used for cracking seeds, sifting mud, or tearing flesh. All spiders have silk glands, which they use for many purposes, the most familiar being the construction of delicate aerial webs by the orb-weaving spiders. Even spiders that don't ensnare their prey use their silk to fashion shelters, wrap their eggs, or line their underground burrows. In New World tarantulas, another preexisting structure, their hairs, has been modified to perform a remarkable number of defensive roles. But *Theraphosa* may provide the single best demonstration of the importance of being hairy. Despite its large size and powerful fangs, the spider uses its hairs to hiss, to throw up a cloud of irritating barbs, to entrap parasitic fly larvae when molting, and to protect its unhatched young. □

Paintings by Douglas Henderson

A pod of ichthyosaurs—Stenopterygius *adults and their young—pursue and attack a group of squidlike cephalopods.*

Ancient Mariners

Some predacious ichthyosaurs were built for speed, others for stealth

by Judy A. Massare

Through the clear, sunlit waters, the predators spotted their quarry. Members of a small pod, the dozen hunters effortlessly picked up swimming speed and gave chase. Their back fins occasionally broke the surface as they rose to breathe. Then they arched and descended, their crescent-moon-shaped flukes the last part to disappear under the waves. The prey, a congregation of squidlike cephalopods, could not outswim their pursuers, swift and agile as fish. Once overtaken, many were grasped and immobilized by their attackers' battery of small teeth.

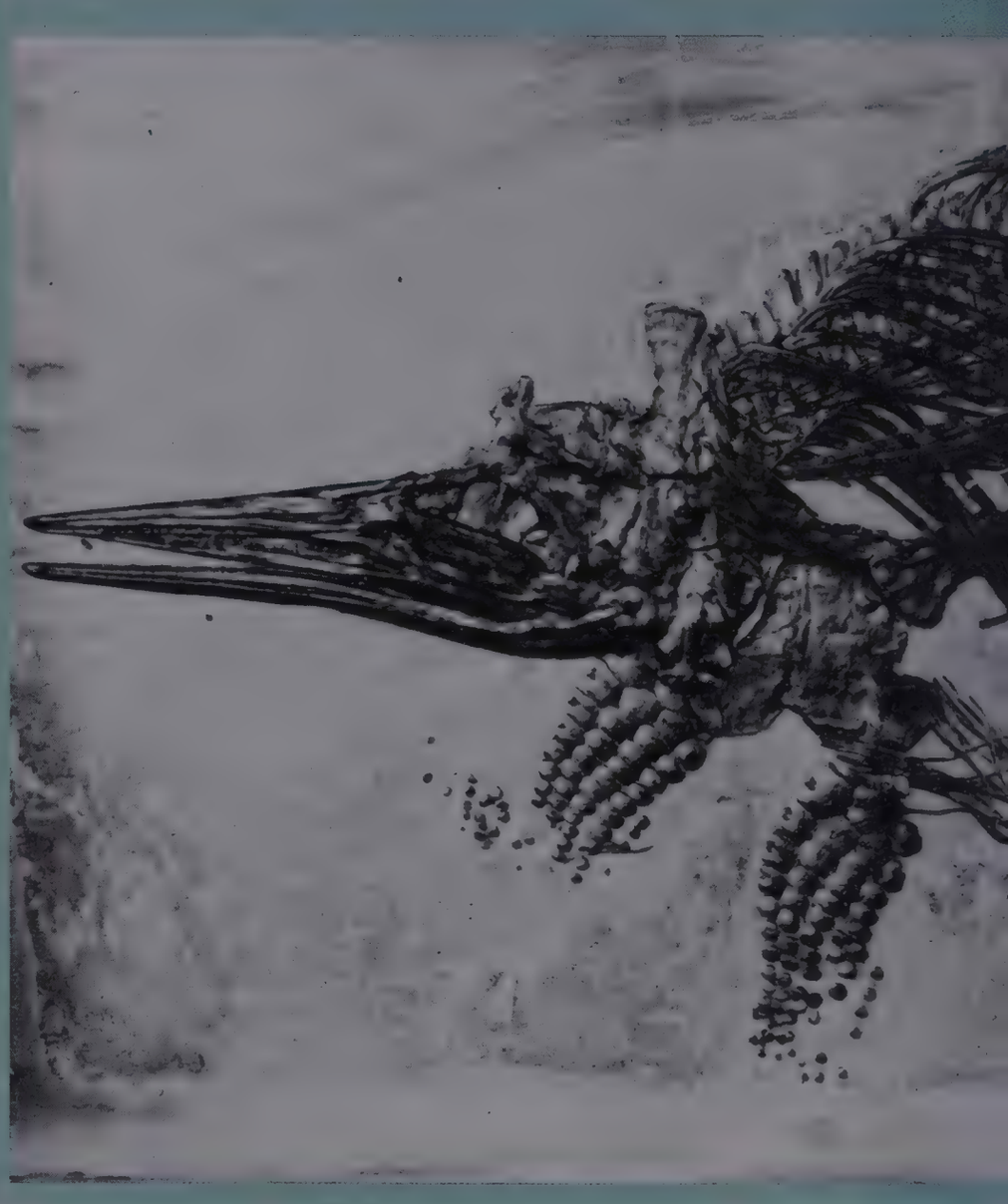
The long-extinct predators in the above scenario, ichthyosaurs known as *Stenopterygius,* were shaped like fish, had heads like those of reptiles, and flippers and tail flukes like those of whales. Paleontologists of the early nineteenth century examining the fossil remains of these creatures and their relatives gave them the name ichthyosaurs, or "fish-lizards." Marine reptiles, ichthyosaurs inhabited the world's oceans from about 85 to 245 million years ago. More closely related to lizards than to either dinosaurs or crocodiles, ichthyosaurs ranged in size from the three-foot *Mixosaurus* to the forty-foot *Shonisaurus,* the largest vertebrate of its time—210 to 230 million years ago—on land or sea. But the best-known ichthyosaurs, and the ones that were first studied, including *Stenopterygius,* were of more moderate size, some six to nine feet in length. They are preserved in rocks some 190 to 200 million years old from Lyme Regis, in southern England, and from Holzmaden, in southern Germany. The black, bituminous shale of Holzmaden preserves not only fossilized skeletons but also carbonized skin impressions, clearly outlining the body, including limbs, tail, and dorsal fin. These ichthyosaurs bear a striking, although superficial, resemblance to modern dolphins, and they were comparable swimmers.

Ichthyosaurs gave birth to live young in the water. One fossil from Holzmaden clearly shows a small ichthyosaur in the birth canal of the adult, leaving little doubt about the animal's mode of reproduction

ROCK-A-BYE, ICHTHYOSAUR

The preservation of embryos and juveniles is a rare occurrence in the fossil record. The tiny, delicate skeletons are usually scattered by scavengers or destroyed by weathering before they can be fossilized. Ichthyosaurs had a higher chance of being preserved than did terrestrial creatures because as marine animals, they tended to live in environments less subject to erosion. Still, their fossilization required a suite of factors: a slow rate of decay of soft tissues, little scavenging by other animals, a lack of swift currents and waves to jumble and carry away small bones, and fairly rapid burial. In short, the animals had to have died in a protected environment and to have escaped being fed upon by scavengers or ravaged by bacteria. Given these factors, som areas have become a treasury of well-pre served ichthyosaur fossils. But even mor remarkable than the fine preservation is th unexpected concentration of ichthyosaurs i some localities.

The deposits at Holzmaden, German present an interesting case for analysis. Th ichthyosaur remains are found in black, b tuminous marine shales deposited abou 190 million years ago. Over the years, thou sands of specimens of marine reptiles, fish and invertebrates have been recovered fro these rocks. The quality of preservation outstanding, but what impresses me eve more is the number of ichthyosaur fossi containing preserved embryos. Most of th



and raising some interesting questions about how such a transitory event came to be fossilized. Unlike many seagoing reptiles such as sea turtles and saltwater crocodiles, which haul out on land to lay eggs, sea snakes and some lizards retain eggs within the body as the embryos develop, a process known as ovoviviparity. This differs from mammalian placental reproduction in that the embryo in the egg sac gets its nourishment from the egg yolk, not from the mother. Ichthyosaurs developed ovoviviparity, an adaptation to life in the sea, early in their evolution. Even the most primitive ichthyosaurs display many adaptations to a marine habitat and are very different anatomically from terrestrial reptiles. Few ichthyosaurs retained even a vestige of a sacrum, the connection between the pelvis and backbone that is necessary for crawling on land, and their vertebrae were simple, lacking the bony struts that stiffen and strengthen the backbone of land animals for support. By freeing ichthyosaurs from the necessity of visiting land to lay eggs, ovoviviparity may have been a major factor allowing even early ichthyosaurs to develop great specialization as swimmers.

The number of embryos found in fossil ichthyosaurs ranges from one to a record eleven. Because ichthyosaurs were carnivorous, some doubt exists as to whether all these remains were embryos or whether some merely represent a last meal. The position of a small ichthyosaur within an adult is critical to this question. A small, whole ichthyosaur in the pelvic region, especially one that appears to be in or near the birth canal, is probably an embryo, whereas a jumbled one in the gut region, especially if it is associated with cephalopod hooklets or other likely stomach contents, is apt to have been dinner. The size of the suspected embryo is another important criterion. No known juvenile ichthyosaurs have skulls less than about six inches long, so smaller individuals within adults are probably embryos.

Such well-preserved fossils as those from Holzmaden not only provide a window on ichthyosaur biology but also give us an ecological perspective on these animals as the dominant large marine predators of their time. The ichthyosaurs most familiar to the public date from the later part of the Early Jurassic, some 190 million years ago. They were superb swimmers. Their streamlined bodies; crescent-shaped, or lunate, tails; and dorsal fins gave them speed, maneuverability, and sustainability. The various genera also display an array of tooth forms, suggesting that they filled nearly all the large predator niches. The largest ichthyosaur from the Holzmaden shales, *Leptopterygius,* some twenty-six feet long, pursued and de-

regnant females belong to two species of *tenopterygius,* the most common Holzaden ichthyosaur. Ichthyosaurs with emryos have been reported from six different vels of the shale in a small area around olzmaden, suggesting that a specific site as used by large numbers of ichthyosaurs peatedly over time. The embryos are quite dvanced in their physical development; eir paddles, for example, are already well rmed. One specimen is even preserved in e birth canal. In addition, the shale conins the remains of many twenty- to thirtych-long "newborns."

Why are there so many pregnant females nd young at Holzmaden when they are so re elsewhere? While the quality of preservation is almost unmatched, and quarry operations have been carried out carefully with an awareness of the value of the fossils, these factors alone fail to account for the concentration of pregnant ichthyosaurs in a particular place very close to their time of giving birth.

I believe that Holzmaden was a breeding and birthing ground, similar to some of the shallow, nearshore areas frequented by whales today. Like such whales as grays and humpbacks, ichthyosaurs were wide ranging. Such animals could well have developed a behavioral adaptation for congregating at a certain time of the year in a spot particularly favorable for giving birth. These nurseries may have been in calm waters, and the sheer numbers of mothers and young may have afforded them some protection from predators, such as the ferocious ichthyosaur *Leptopterygius.*

Although they were open-water, mobile creatures, ichthyosaurs, unlike whales and dolphins, lacked the acute hearing necessary for long-distance aquatic communication. Thus, their seasonal congregations may also have served as social arenas where the sexes could meet and mate.—*J. A. M.*

A female Stenopterygius *from the Holzmaden deposits was preserved along with seven embryos, an unusually high number. One is near the pelvis.*
AMNH

voured large prey, perhaps even other ichthyosaurs. Its sharp, robust teeth show the same type of wear as that seen on the teeth of living killer whales. Other ichthyosaurs were more like dolphins, both in size and in their preference for squidlike cephalopod prey. Their teeth are fairly small and not very pointed, suggesting that they were used to grasp rather than impale prey. Still others, such as *Eurhinosaurus,* had sharp, slender teeth ideal for piercing small fish.

Such finely tuned adaptations represent the result of tens of millions of years of evolutionary experimentation. Although later ichthyosaurs shared the basic body plan of those of the Jurassic, many earlier ones did not. The fossil record of ichthyosaurs goes back to the Early Triassic period, approximately 240 to 245 million years ago, some 15 million years before the first dinosaurs appeared. Although the earliest ichthyosaur fossils are fragmentary, they indicate that a variety of ich-

A lone hunter, the long, sinuous ichthyosaur Cymbospondylus *may have ambushed prey that inhabited reefs.*

thyosaurs existed and that they ranged from Europe's oceans to those of North America, Japan, and China. These reptiles differed greatly from their Jurassic descendants in body plan, and thus also in life style and general ecology.

The best known of the Triassic ichthyosaurs is *Mixosaurus,* from the fossil beds of Monte San Giorgio in Switzerland and Besano in Italy. More elongated than most Jurassic ichthyosaurs, *Mixosaurus* most likely also had a broad, rather than a crescent-shaped, tail fin. The clue to the probable shape of an ichthyosaur tail is the presence or absence of a bend in the lower backbone. Jurassic species with lunate tails have a distinct "tail bend," where the backbone supported the lower lobe of the tail fin (*see* "Bent out of Shape," *Natural History,* May 1990). While *Mixosaurus* lacked a tail bend, it displayed an unusual feature—greatly elongated neural spines at about the position of the tail bend in later ichthyosaurs. These spines would have broadened the tail, in somewhat the same way that the tails of crocodiles are broadened, or perhaps the spines supported the upper lobe of a very asymmetrical tail fluke.

The less compact, more elongated body form of most Triassic ichthyosaurs is seen in the extreme in *Cymbospondylus,* from the Middle Triassic. It had a long torso, with sixty-five vertebrae between the head and pelvis, compared with about fifty in most Early Jurassic ichthyosaurs. Such sinuousness would have increased drag for a given size and made such Triassic forms less efficient swimmers.

Although slower in the water, Triassic ichthyosaurs were widespread and diverse, successful by all the usual measures. Rather than viewing them as mere precursors of the later streamlined forms, I prefer to think of them as adapted to a different kind of life. In their overall proportions, and probably in their swimming abilities as well, Triassic ichthyosaurs can be compared to modern crocodiles. Rather than pursue prey over long distances, crocodiles lie in wait for prey, then lunge at it with a single burst of speed. For them, endurance is not as important as acceleration. Long-bodied animals that can undulate in a large wave are better at picking up speed than at high-speed endurance. A broad tail would have been ideal for producing the necessary thrust for a rapid burst of speed. This was likely the strength of Triassic ichthyosaurs. I believe that like crocodiles, they were ambush predators. What we see in Jurassic ichthyosaurs, in contrast, are animals designed for minimizing drag, for fast, continuous swimming in open water. Thus, an ecological shift must have occurred among the ichthyosaurs late in the Triassic, a transition period for which we have few fossils. Interestingly, seagoing crocodiles known as teleosaurs appeared in the Early Jurassic. Their long, narrow bodies and long, broad tails are reminiscent of the adaptations for ambush predation in Triassic ichthyosaurs. Perhaps the teleosaurs took over the ambush predator niches vacated by ichthyosaurs at the end of the Triassic.

Because of their adaptations for rapid and prolonged pursuit of prey, one might expect Jurassic ichthyosaurs to have lived in deeper water than their predecessors. The picture, however, is murky. While *Mixosaurus* remains are found in rocks that originated in shallow lagoons, fossils of larger Triassic ichthyosaurs, such as *Cymbospondylus,* come from deepwater limestones. Most of these limestones were deposited near offshore reefs, a feature that would have added the necessary physical complexity required to ambush prey. Many of these fossil reefs, however, were not the large, wave-resistant structures that we recognize as reefs today, and they give few clues as to just how the animals would have used them for concealment and surprise attacks.

Another ecological difference between Triassic and younger ichthyosaurs is reflected in their teeth. A number of Triassic ichthyosaurs, such as *Mixosaurus,* possessed slender, sharp front teeth and blunt, robust back teeth. This suggests that they could have eaten a variety of prey, crushing shellfish with the back teeth or cheek teeth and impaling softer and perhaps quicker prey on the points of the front teeth. Later ichthyosaurs had just one kind of tooth in their jaws, as is the case in living whales and dolphins. Many species of Triassic ichthyosaurs probably availed themselves of a whole spectrum of seafood. This is consistent with the idea that Triassic ichthyosaurs were ambush predators that waited for prey to swim or crawl by, rather than active hunters. Teeth capable of processing anything that presented itself would have been an advantage. Jurassic ichthyosaurs, in contrast, were built for sustained swimming and could search for specific quarry over vast hunting grounds. Prey specialization became a possibility.

Ichthyosaurs thrived for the better part of 160 million years and reached their peak diversity in the Early Jurassic. Periodically, however, critical events, such as changes in climate or in water temperature and levels, changed the composition of the marine predator community. One such episode occurred about 170 to 185 million years ago. By the end of this time, ichthyosaurs had declined in diversity and abundance. The many varieties seen in fossils from deposits like those at Holzmaden were gone. A new predator was in the ascendant. Plesiosaurs, especially the short-necked pliosaurs, became more abundant and took over many of the niches formerly filled by ichthyosaurs.

Whether this replacement resulted from competition—something extremely difficult to determine from the fossil record—or whether plesiosaurs were less affected by some extinction event that decimated the ichthyosaurs is unknown. But this marked the beginning of the end for the ichthyosaurs. By the Cretaceous period, beginning some 145 million years ago, all ichthyosaur species were so similar that they have been grouped together into a single genus, *Platypterygius.* The last ichthyosaur vanished about 85 million years ago, fully 20 million years before the demise of the dinosaurs. Although not as climactic a decline as the dinosaurs', the disappearance of these superb marine predators is no less an enigma. □

A four-toed elephant-shrew at the foot of a forest tree at Gedi Ruins in Kenya
Galen B. Rathbun

The Fairly True Elephant-Shrew

The male of this odd, long-nosed mammal is faithful but not fatherly

by Galen B. Rathbun

In 1970, as an eager graduate student, I traveled to coastal Kenya in search of dugongs. Some of these gentle cousins of the better-known manatees are known to live in the shallows off the eastern coast of Africa, and I hoped to make them the focus of my dissertation research. However, after spending several months in the field without spotting a single dugong, I was facing the very real prospect of failure. Discouraged, I took a day off to visit the Swahili ruins at Gedi, north of Mombasa. There, beneath towering trees and crumbling mosques, I saw my first elephant-shrews. As I watched the little mammals foraging among the ruins, their golden rumps flashing in patches of sunlight on the forest floor and their long snouts constantly probing the leaf litter, I was immediately captivated. I abandoned the elusive dugong and began what turned out to be a six-year study, in the wild and in captivity, of the ecology and behavior of elephant-shrews.

As I soon discovered, virtually no fieldwork had been done on elephant-shrews, so almost everything I discovered about them was new to biology. Neither elephants nor shrews, these mammals, also known as jumping shrews, came by their common names because of their long, trunklike noses; because like true shrews, they feed on invertebrates; and because of the impression—false—that they can jump on their large rear legs like kangaroos. I came to prefer the monikers hose-noses or flute-snoots.

Ever since the first species was described in 1829, biologists have disagreed on the elephant-shrews' ancestry. Over the years, they have been mistakenly associated with true shrews, tree-shrews, ungulates, and monkeys, but most biologists now agree that they have no close living relatives and that they belong to their own group, the Macroscelidea (from "long" and "thigh" in Greek). To understand the evolutionary origins of elephant-shrews, some paleontologists think we would need to go back 50 or 60 million years, to the distant ancestors of rabbits and hares.

The Macroscelidea, including all extinct forms, are limited to Africa. The fifteen living species share a similar body plan, but they vary greatly in size: some are as tiny as a mouse; others as large as a small cat. Adaptable creatures, elephant-shrews can be found in nearly all types of African habitats. Among the smallest, the one-and-a-half-ounce short-eared elephant-shrew (*Macroscelides proboscideus*) lives in the Namib Desert and other parts of arid southwestern Africa. The slightly larger rock elephant-shrew (*Elephantulus myurus*) lives in huge boulder fields, or *kopjes,* in southern Africa, while the North African elephant-shrew (*E. rozeti*) inhabits arid montane areas of northwestern Africa at elevations up to 8,200 feet.

Several species, including the seven-ounce four-toed elephant-shrew (*Petrodromus tetradactylus*), occupy the vast, arid grasslands and woodlands of central, eastern, and southern Africa. The three species of giant elephant-shrews (genus *Rhynchocyon*), weighing in at a hefty nineteen ounces or so, live in forested areas of central and eastern Africa. With their contrasting, bold colors of amber,

Jen and Des Bartlett; Bruce Coleman, Inc.

Its fuzzy fur identifies this golden-rumped elephant-shrew, below, as only recently weaned, but it is already proficient at poking around in the leaf litter for earthworms and other invertebrates to eat. A pair of elephant-shrews, right, pause together on a fallen log in the underbrush.

Galen B. Rathbun

gold, black, rust, and white, these latter elephant-shrew species are among the most colorful of small mammals.

All elephant-shrews eat mainly invertebrates, such as insects, spiders, centipedes, millipedes, and earthworms. An elephant-shrew uses its nose to find prey and its long, extensible tongue to flick small food items into its mouth, much like a miniature anteater. Relatively large prey are more of a challenge. A giant elephant-shrew struggling with a six-inch-long earthworm, for example, first pins its prey to the ground with a forefoot. Then, turning its head to one side, it chews pieces off the squirming animal with its cheek teeth, much like a dog chewing a bone. This is a sloppy process, and many small pieces of worm drop to the ground; these are simply flicked up with the tongue. Some elephant-shrews also feed on small amounts of plant matter when available, especially new leaves, seeds, and small fruits.

All elephant-shrews have long, thin antelopelike legs that enable them to run exceptionally fast (up to seventeen miles per hour in *Rhynchocyon*). Most species reproduce several times a year. Litters are made up of one to four fully furred young. The majority of elephant-shrew species are active mostly at dawn and dusk; some are also active at night, while yet others restrict their activity to daylight hours. All species, however, are active during at least a few daylight hours, and with patience, they can be observed with relative ease.

The main object of my attention at Gedi Ruins was the golden-rumped elephant-shrew (*R. chrysopygus*), found only in a narrow, fragmented strip of lowland dry forest along the coast of Kenya, from the Somalia border south to Mombasa. I chose Gedi as a study site because the forest canopy there is only about sixty-five feet high and the understory is fairly open, important factors if I hoped to watch wild animals in the forest.

I captured about twenty-five animals and tagged each individual on both of its long, skinny rear legs with a unique combination of colored rings designed for banding birds. I then regularly walked a grid of small paths that I cut through the forest and recorded where and when I encountered marked individuals. I had to move very slowly and carefully along the paths so that I would not frighten the animals when I came upon them. If I was successful, I used binoculars to watch them. If not, they noisily bounded out of sight.

Rhynchocyon (from "nose" and "dog" in Greek) is active only during daylight hours, spending nights in a nest made of dead leaves on the forest floor. Each individual elephant-shrew maintains several widely spaced nests, which are used on different nights. Golden-rumped elephant-shrews spend nearly four-fifths of their active time slowly walking about on the forest floor foraging in the continuous carpet of dead leaves. About 80 percent of my sightings were of lone animals, which at first appeared to confirm the general view that this species was solitary. Most mammals that are solitary show little preference for individual mates, but rather have various forms of promiscuous mating systems. After several months of gathering information on *Rhynchocyon,* however, I realized that this species had a social organization that could best be described as a type of monogamy. Male–female pairs were distributed throughout the forest,

each occupying an exclusive territory. The home ranges were surprisingly consistent in size, averaging four and a half acres each. Furthermore, and most important, the pairs were stable, changing only with the death or disappearance of a member.

Occasionally, I observed wild zigzag chases through the forest, one elephant-shrew in hot pursuit of another. Several times, the chase led to a fight, and the two grappling animals disappeared in a blur of flying leaves. The chases, which usually ended on borders between the home ranges of adjacent pairs, almost always involved members of the same sex: males chased males and females chased females. Both sexes also scent marked their territories with a secretion from a large gland at the base of the tail.

When a female entered estrus, the pair became inseparable, the male following his mate closely everywhere she went. His protectiveness almost guaranteed that only he got to mate with the female.

The mating period, which lasted several days, was followed by six weeks of gestation, when the pair returned to their "solitary" habits. The female then gave birth to a single young in one of her leaf nests. Unfortunately, I had trouble determining which nest contained the baby, so I was unable to observe the first few days of an elephant-shrew's life. I estimate that the young remained hidden in the nest for about ten days. When it emerged, it was weaned and essentially independent of its mother. I rarely saw a father associate or interact in any way with a mother–young pair: no grooming, no sharing of food. And once the young was weaned, the female, too, continued her more solitary ways. The juveniles were tolerated on the parental territory until they found their own territory or disappeared—presumably eaten by predators. At all times, however, the male and female stayed within their borders, spending a significant amount of time together only every six to eight weeks to mate. Unless, that is, death intervened.

How do elephant-shrews die? Field biologists, or at least those working with small mammals, may know when an animal is born into their study population, but when an individual disappears, the time and cause of its demise are less certain. I suspected, for example, that southern

banded harrier eagles, which were common at Gedi, took a toll on elephant-shrews, because I frequently saw them hunting in the forest there. Only once, however, did I see an eagle successfully capture an elephant-shrew, in this case a recently weaned juvenile.

There were other potential predators at Gedi, such as mongooses, wild cats, and snakes. These, too, were seldom cooperative enough to hunt when I was around, but there was one time when I came close to understanding what it might feel like to be an elephant-shrew caught unawares. I was sitting on one of my trails, intent on an elephant-shrew foraging about fifteen feet away, when I heard a soft rustling in the leaves behind me. Thinking it was another elephant-shrew, I remained motionless so that I would not disrupt what I hoped would be an interesting interaction. But as the rustling got closer, something told me that the sound was not right for an elephant-shrew; it just seemed too consistent. As I slowly lowered my binoculars and cautiously turned my head, I found myself facing a seven-foot-long forest cobra coming up the trail toward me. I sprang to my feet and, followed within seconds by the elephant-shrew, retreated farther into the forest, where I watched the cobra cross the spots where the elephant-shrew and I had been just a moment before. Herpetologists have reported finding partly digested *Rhynchocyon* in dissected cobras and black mambas, and I have little doubt that these snakes were responsible for the disappearance of some of my animals.

Final as it is for the victim, death seemed to have little effect on the reproductive output of the surviving mate. Lost mates were replaced within a couple of days by recently weaned or otherwise unattached animals.

After nearly two years at Gedi Ruins, I had learned enough about the golden-rumped elephant-shrew to know that its social behavior was unusual for a mammal—only about 7 percent of all mammals are monogamous. I decided that in order to better understand *Rhynchocyon,* I needed to compare it with another elephant-shrew, preferably one that lived in a very different habitat. I spent a year studying the behavioral ecology of the rufous elephant-shrew (*Elephantulus rufescens*) at a remote safari camp called Bushwhackers, just outside Tsavo East National Park in Kenya. This species, at two ounces, is about one-tenth the weight of the golden-rumped. It also has a shorter nose, less spindly legs, and larger eyes, and with nearly uniform gray fur, it is not as colorful.

Elephantulus ("little elephant" in Greek) is widely distributed in arid scrub and woodlands of eastern Africa. These elephant-shrews are active mostly at dusk and dawn, which adds to the difficulties of observing them in the dense, low brush that makes up their habitat. Fortunately, unlike golden-rumped elephant-shrews, which wander unpredictably through their territories, rufous elephant-shrews confine their movements to a complex network of trails. By precariously perching on ten-foot-high towers placed throughout the study area, I was able to watch the animals move about on their trails below me. Being ten feet above such small creatures, of course, made identifying particular animals tricky, but thanks to binoculars and the colored ear tags that I put on a number of the animals, I was able to follow the movements of some twenty individuals.

To my surprise, despite the considerable differences in their body size and habitat, the two species seemed to have a similar social organization. Nearly all my sightings were of lone individuals, but as

A mother rufous elephant-shrew peeks over the edge of a rock, left, at her two day-old offspring, born in captivity. Standing on tiptoe to look larger and thus more intimidating, a pair of free-ranging female rufous elephant-shrews, below, confront each other at a territorial border.
Photographs by Galen B. Rathbun

before, when all sighting records were plotted on a map, they showed that female–male pairs lived on exclusive home ranges, each about four-fifths of an acre. Territorial defense was again sex specific, and again females and males interacted mainly when the females were in estrus. At that time, the males became very possessive of their partners, chasing off intruding males. As in *Rhynchocyon,* only territory holders bred, as far as I could tell. Litters of one or two young were produced about every two months. Like male golden-rumped elephant-shrews, male rufous elephant-shrews seemed to ignore the female when she was raising the young. In fact, I rarely saw a male near his mate or their young at this time.

One of the more interesting aspects of rufous elephant-shrew biology is the network of trails maintained by the pair. This species uses neither burrows nor nests, but relies instead on the system of trails to search for food, make unobstructed escapes from predators, sleep, and even give birth. Living in the open on trails this way is possible only because these elephant-shrews are especially swift (even the young are able to race along the trails within a few hours of birth) and because they fastidiously maintain the trails. Out of the ten to fourteen hours a day that adults are active, about 30 percent is spent carefully sweeping aside leaves, twigs, and grass, leaving a clear path through the leaf litter. At Bushwhackers, the males seemed to spend more time cleaning trails than did the females, an observation I later confirmed with a captive colony I established at the Smithsonian Institution's National Zoological Park in Washington, D.C. There, males spent about 40 percent of their waking hours trail cleaning; females, about 20 percent.

In the field, I found that *Elephantulus* uses several different glands to scent mark, but this behavior was too complicated to be understood by field observation alone. Again, the colony at the National Zoo proved invaluable. Biologist Fred Koontz spent several years unraveling the role of scent marking in rufous elephant-shrew society. He found that they mark their territories with a secretion produced from a large gland on their chest. As the elephant-shrews travel about on their territories, they periodically rub this gland on the ground, leaving behind a distinctive odor. The scent is used to communicate individual identity, sex, reproductive condition, and, of course, location. Koontz thinks that scent marking helps the elephant-shrews establish and maintain contact with their mates, their young, and adjacent territorial pairs without frequent visual contact.

When death comes to the rufous elephant-shrew, the most common cause, I suspect, is snake predation. I saw five attempts by speckled sand snakes to capture rufous elephant-shrews, and one was successful. Other possible predators are mongooses, genets, servals, and birds of prey, especially owls.

When I began my research in the Gedi Ruins, I did not know that German biologists Franz and Elinore Sauer were just completing their seven-month-long field study of the short-eared elephant-shrew in the Namib Desert. What they had found was a social system similar to what I dis-

Some elephant-shrews make nests out of dead leaves or burrow in loose soil; others take advantage of existing shelters, like the termite mound below. With their big eyes, big ears, and small size, elephant-shrews, right, bear a superficial resemblance to small rodents, but they actually have no close living relatives.
Phyllis Greenberg

covered in the two species I studied: limited monogamy, with no apparent paternal assistance in raising young (and clearly no need for it, since young survived without it), but a pair bond that lasts until death. Generally speaking, mammals are less apt than birds to be monogamous, but when they are, paternal care is common: fathers may groom, feed, defend, or carry their offspring. Examples include most human societies, of course, but also many species of other primates, such as marmosets, and many carnivores, such as foxes and wolves. In elephant-shrews, however, no such fatherly help exists. Why then do these three species of elephant-shrews, belonging to three different genera and living in three quite different types of habitat, engage in any sort of monogamy at all?

All three species—whether in desert, forest, or bushland—feed primarily on small terrestrial invertebrates. Typically, these food items are fairly evenly distributed throughout the habitat, especially where leaf litter or desert gravels are more or less uniformly distributed on the ground. In addition, the abundance of invertebrates does not vary greatly from wet to dry season. This is in contrast to the foods that many other mammals rely on, which may be highly seasonal, predominately clumped, or very dense. Examples include monkeys that seek trees that fruit only once a year, lions that rely on herds of antelopes, and some mice that feed on grasses. The food supply of elephant-shrews, therefore, is generally a reliable one that is spread out, with no particularly rewarding clumps, so the animals must cover a fair bit of ground in order to find enough to eat.

Under these conditions, females would very likely be widely dispersed, and any male that attempted to mate with several of them would be forced to spend a great deal of time searching for them instead of for food. And when he finally found a sexually receptive female, he might well have to compete for her with other males, some of which may have reached the prize before he did. In a dispersed population, a better reproductive strategy for the male may be to stick to one female and guard her closely, thus making sure that he, and only he, is nearby when she comes into estrus. And since females can breed several times a year, a stay-at-home male may sire as many as a dozen offspring a year.

Another reason for the similar social organization in the three species of elephant-shrew may simply be their shared ancestry. The constraints of genetic history may contribute to a relatively inflexible social system. Determining the relative roles of "phylogenetic inertia" and environmental factors is difficult. However, certain observations suggest that both are important. Sex-specific aggression, for example, is probably innate and may be why only one female elephant-shrew occupies any single territory. But the size of the territory, which determines how far apart females are and thus influences the males' reproductive strategy, is more likely determined by the environment.

On several occasions in both of the species I studied, a territorial female lost her mate. Within a day or two, a male from an adjacent territory began defending both his old territory and the widowed female's. This situation was always short-lived, however, because the would-be polygynous male was soon driven back to his original territory by an unattached "floating" male that came in to pair with the widow. The amount of real estate necessary to keep company with more than one female is apparently more than a single male can defend.

The rufous elephant-shrew is intriguing to me because certain aspects of its trail-building behavior suggest the possibility of an intermediate stage between limited monogamy and a more cooperative pair bond. As I saw in both the field and the zoo, the male spends considerably more time—the zoo work suggested 50 percent more—working on the trails than does his mate. Could it be that without this indirect paternal contribution, a pair could not successfully raise their young? If so, could it be that I found a species that is indeed intermediate between limited monogamy and the sort of social arrangement we humans generally associate with monogamy, in which both parents must contribute substantially to the care of the young? I'd like to know the answers to these questions, but for the foreseeable future, I can only hope that someone else will search for them, for I have gone back to the sea, pursuing not dugongs this time, but information that will insure the survival of sea otters off the coast of California. □

Consciousness-Raising III

by John Alcock

In *Animal Minds* Donald Griffin continues his crusade for the recognition of animals' mental abilities, which he began in 1976 with the publication of *The Question of Animal Awareness*. The central theme of his third book on the subject is that an unwise taboo on thinking about conscious awareness in nonhuman animals has blocked investigation into something that could and should be studied scientifically with great profit.

There is little doubt that most scientists have avoided the question of whether the "lower" animals have any of the attributes that humans commonly label "consciousness" or "thinking." As Griffin points out, part of the reluctance stems from the influence of the behaviorist school of psychology, which specifically rules out any attempt to examine mental processes, even in human beings. But many nonbehaviorists also question the productive investigation of nonhuman consciousness, primarily because of the practical difficulties inherent in trying to figure out what other individuals are thinking, especially when these individuals are members of another species.

ANIMAL MINDS, by Donald R. Griffin. *University of Chicago Press, $24.95; 320 pp.*

Griffin acknowledges that no one has even begun to test the proposition that nonhuman animals think in a manner similar to that of human beings. That there is no real evidence either way is the basis for his arguing that it is just as plausible to advocate that animals "think" as to deny that they do. To persuade us that many animals are far more than "sleepwalkers" or robots, Griffin surveys at length three lines of evidence that to him are suggestive of consciousness: (1) the ability of some animals to change their behavior adaptively under different and sometimes novel circumstances, (2) certain similarities in brain neural function between lower animals and humans, and (3) the complex communicative abilities of many species.

Griffin presented most of this evidence in his second book, *Animal Thinking*. Although he discusses some new material in *Animal Minds*, the latest treatise really constitutes a revised edition of his earlier work, with a very similar organization and central theme. However, those who are interested in the versatility and complexity of animal behavior will find many intriguing examples neatly summarized and discussed in a readable fashion in *Animal Minds*. The ability of certain small birds to open milk bottles, the capacity of a Clark's nutcracker to remember where it has hidden on the order of a thousand small caches of seeds, the playful behavior of foxes with small prey, the cooperative hunting of lions, flexible communication in weaver ants, the skill pigeons exhibit in categorizing visual stimuli, the famous dances of honey bees, the honey guide's ability to lead humans and other animals to distant bee colonies, the "linguistic" feats of chimpanzees and gray parrots, the complex deceptive signaling of fireflies and mantis shrimps, all this and much more is grist for Griffin's mill.

The various stories are entertaining in their own right, but each and every one is offered up to hammer home the idea that animals other than ourselves exhibit the kind of behavioral sophistication that is compatible with conscious thought. The underlying logic of the argument goes as follows: Conscious awareness influences at least some of the behavioral decisions that human beings make; our consciously driven behavior is complex and versatile; because other species also possess complex and versatile behavioral attributes, they too might well possess something like the consciousness that characterizes human psychology. The rationale underlying this position requires that caddis flies and honey bees, weaver ants and bowerbirds, any species that exhibits behavioral complexity or versatility (and almost every species does) be a candidate for consciousness of the sort humans exhibit. Griffin repeatedly concludes, after an examination of one or another example, that the complex or versatile behavior of species X suggests or is indicative of or could be interpreted as evidence that the animal was thinking about the consequences or goals of its actions.

And Griffin is right. It is possible that as Egyptian plovers wet their belly feathers before returning to cool the chicks they have left far away they are thinking about keeping their young cool. Or that as caddis fly larvae repair a damaged shelter they are thinking about what the end product will be like and how to accomplish this end. In fact, any animal carrying out any behavior could conceivably be consciously aware of what it is doing and why. If nonhuman animals do think, perhaps they can (as Griffin argues) make better (more adaptive) decisions by consciously considering the "multiple factors that must be evaluated, and the unpredictable details."

Griffin tells us often that by keeping an open mind to this possibility progress will eventually be made on a topic that has great ethical, philosophical, and scientific import. But more than an open mind is needed to investigate a topic scientifically. We need ways in which to test hypotheses in a convincing manner. In this regard *Animal Minds* disappoints, because it offers no practical guidance on how to test whether consciousness is an all-purpose, problem-solving device widely distributed throughout the animal kingdom. Moreover, the book does not discuss in sufficient detail the existing counterhypotheses, permitting readers to evaluate the relative merits of competing proposals and see, in principle at least, how to choose among them.

And there are alternative approaches to consciousness not based on the behavioristic principle that thinking cannot be studied because it does not exist. For example, Richard Alexander, a zoologist at the University of Michigan, has elaborated at

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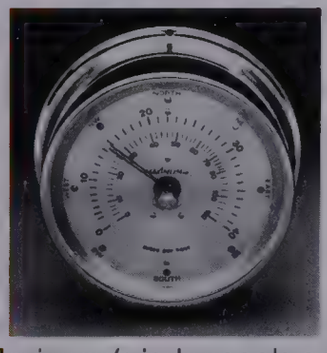

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length upon British psychologist Nicholas Humphrey's proposal that human consciousness is an adaptive tool useful in promoting individual reproductive success in the extraordinarily complex social environment of our species. Alexander believes that human intellectual skills are the product of past selection created by aggression among groups, which favored individuals capable of strategic cooperation (and pacific competition) within their own band in order to deal effectively with potentially aggressive groups nearby. These are the special conditions that might favor individuals with the ability to think through the consequences of alternative plans and to anticipate and thereby manipulate the responses of others, while trying to imagine how their ambitions and actions might be interpreted by potential cooperators and opponents alike.

Griffin refers only in passing to Humphrey and makes no mention of Alexander's views, perhaps because his proposal is so utterly at odds with Griffin's central thesis. If Alexander is correct, human "consciousness" actually consists of several discrete psychological/cognitive abilities, among them self-awareness, mental scenario building, and the effort to interpret the mental states of companions. Whatever human consciousness is, it is (as Griffin acknowledges) the outcome of many millions (or billions) of brain cells. These neurons cost something to build and to maintain; if, in the past, individuals with consciousness networks had not enjoyed a reproductive edge over individuals without these mechanisms, the ability to think consciously would never have spread through human populations to be transmitted to those of us who are around today. The Alexandrian position strongly suggests that the spectrum of traits that we call consciousness may have evolved only in humans and perhaps a handful of other species with similar social structures. Thus, the benefits of thinking can compensate for the physiological and other costs of conscious thought only in a special kind of social environment.

Illustration by Robert Giusti from the cover of *Animal Minds*, by Donald R. Griffin

In contrast, for Griffin, consciousness is essentially a unitary trait that occurs widely throughout the animal kingdom, appearing in all creatures great and small (see the review of *Animal Thinking*, by Colin Beer, *Natural History*, June 1984). Griffin does at the outset acknowledge a distinction between perceptual consciousness and reflective consciousness, the first term referring to a mental awareness of one's perceptions and the second to self-awareness, the introspective ability to think about one's thoughts and recognize their origin. He suggests that most nonhuman examples he discusses are possible cases of perceptual consciousness, but he also argues that the distinction between perceptual and reflective consciousness is not important.

The difference between Alexander's and Griffin's arguments is profound. No one who accepts Alexander's position would be tempted to argue that caddis flies or Egyptian plovers have anything like the same sort of thinking abilities as humans, even in rudimentary form.

How can we evaluate the plausibility of the two theories? One way, admittedly roundabout, is to ask whether mental abilities that we can currently explore are universal and all-purpose (the Griffin posi-

tion) or specialized and highly distinctive solutions to particular ecological circumstances (the Alexandrian position). We know a surprising amount about the stimuli that animals can perceive, and there is no doubt whatsoever that the sensory perceptions of species differ enormously in ways that reflect their special environments and ways of making a living.

Griffin himself contributed greatly to this conclusion with his brilliant research on bat sonar. He showed that a little brown bat uses a highly complex perceptual apparatus that is qualitatively different from those possessed by humans and the vast majority of other animals. These bats detect and track down flying insects in complete darkness by producing volleys of ultrasonic cries and then listening for the echoes bouncing off potential prey. The cries and the resultant echoes occur in a range of sound frequencies that the human ear is totally incapable of detecting.

In these nocturnal, flying, insectivorous mammals, ultrasound perception evidently evolved as a navigational and prey-capturing aid. The link between special perceptual capacities and special ecological problems has been shown over and over in studies of nonhuman animals, many of which have abilities completely absent in ourselves and in most other species. The same is true for learning abilities. Male and female meadow voles, to take just one example, differ dramatically in their spatial learning capacity because male voles wander over much more terrain than do the more sedentary females.

I think that the preponderance of evidence is strong that psychological abilities are discrete solutions to particular ecological problems, not generalized, all-purpose tools suitable for any niche and any species. I will be astounded if consciousness proves to be an exception to the rule. To expect little brown bats to think like humans strikes me as being about as persuasive as the claim that humans share the same sort of perceptual abilities as little brown bats. No harm will come from trying to test whether animals think as we do, however. And if someone can devise a way to perform the necessary experiments, it will say something about the remarkable nature of human consciousness, no matter what it shows about thinking in little brown bats and caddis flies.

John Alcock is a professor of zoology at Arizona State University and the author of Animal Behavior: An Evolutionary Approach *and* Sonoran Desert Summer.

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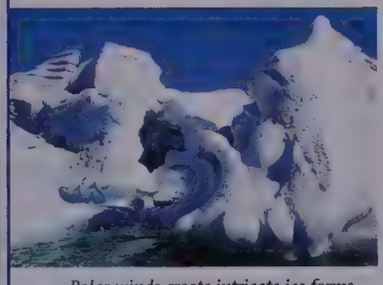

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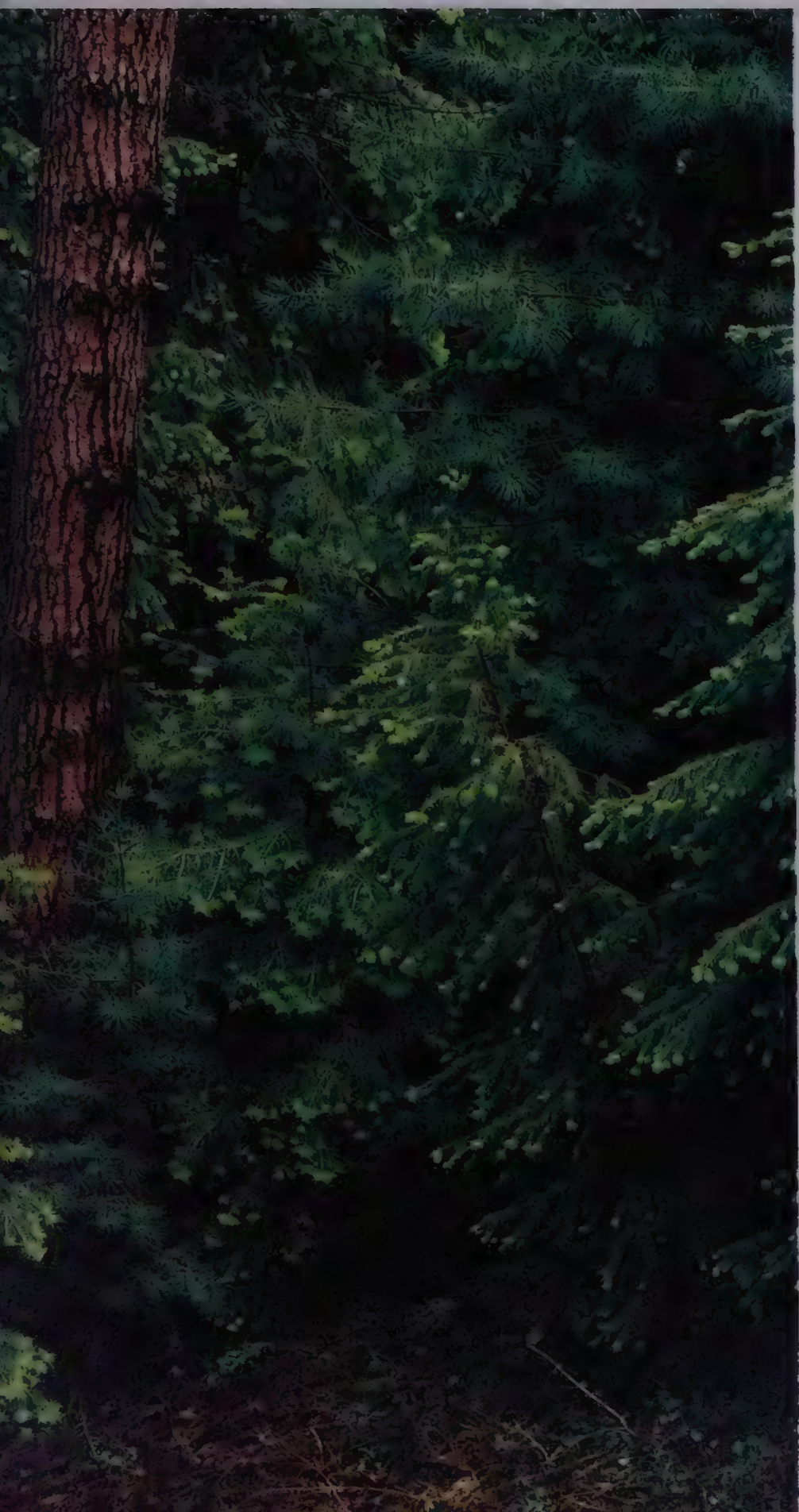
White firs and other trees grow in the montane fir forest atop Mount Lemmon.
Steven C. Wilson; Entheos

Mount Lemmon, Arizona

by Robert H. Mohlenbrock

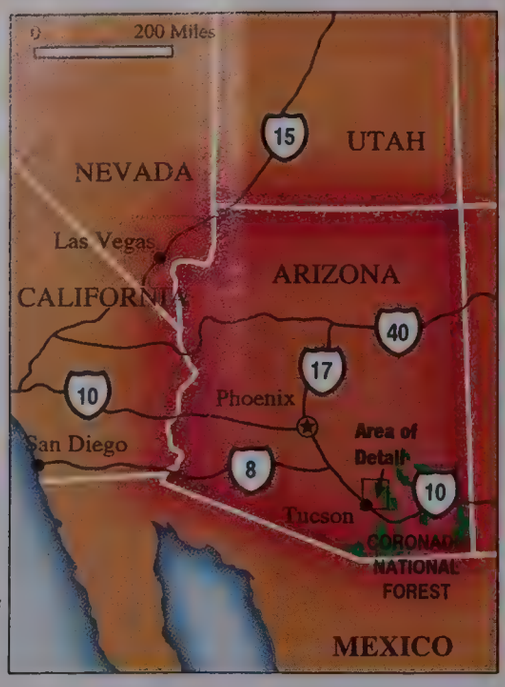


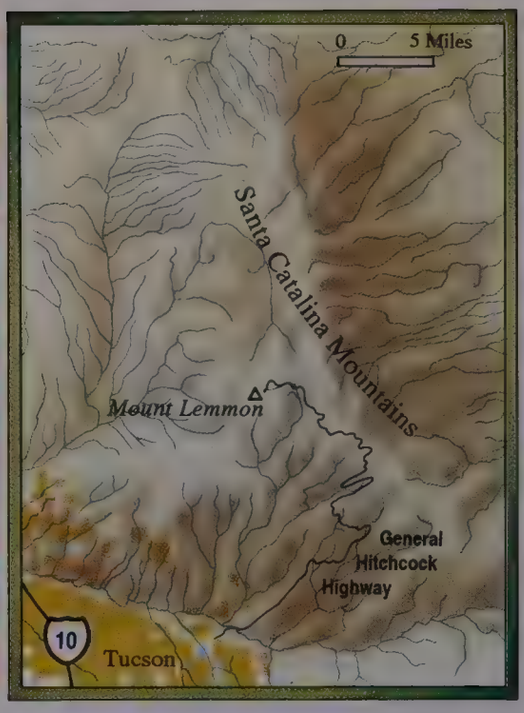
The Santa Catalina Mountains loom high above the north and northeastern boundaries of the expanding desert city of Tucson. Dominated by 9,153-foot Mount Lemmon, the range covers an area of about 200 square miles, most of which is under the jurisdiction of the Coronado National Forest. The Forest Service has provided many campgrounds, hiking trails, and other amenities to serve the nearby metropolis, including paved General Hitchcock Highway, which ascends all the way to the ski area near the top of Mount Lemmon.

The thirty-five-mile drive from Tucson to Mount Lemmon (less than twenty miles as the crow flies) is often equated to driving from Arizona to Canada. The Sonoran Desert, at 2,500 feet above sea level, contains a great variety of cactuses and spiny shrubs, such as ocotillo and cat's-claw acacia. This community grades into a desert grassland with many grasses and several species of large century plants. Above the grassland is the open oak woodland, dominated by Emory oak, Mexican blue oak, and Arizona rosewood. This shades into a pygmy conifer-oak scrub, whose common species are pinyon pine, alligator juniper, Arizona oak, Emory oak, and two species of manzanita. Then, almost imperceptibly, a pine-oak woodland of ponderosa pine, Chihuahua pine, silverleaf oak, and Arizona oak takes over. By 7,300 feet only the ponderosa pine and silverleaf remain, while above 7,600 feet the forest consists entirely of conifers—ponderosa pine, southwestern white pine, and on the summit, a montane fir forest of white fir and Douglas fir.

The differences in vegetation at different elevations are due, in large part, to the amount of moisture available and the position on the mountain, that is, whether the slope is north facing or south facing. The desert zone, for instance, receives only three to fifteen inches of rainfall each year and therefore supports mainly cactuses and various spiny shrubs and small trees that are adapted to arid conditions. This zone extends roughly from 2,500 feet to 4,000 feet on the hotter, drier south slope

Joe LeMonnier





Mount Lemmon

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of Mount Lemmon, but only to 3,200 feet on the cooler, moister north slope. Similarly, the desert grassland community lies between 4,000 and 6,300 feet on the south side but between 3,200 and 4,400 feet on the north side.

The desert is an open community, but higher up the mountain, as moisture becomes increasingly abundant, the habitats become more and more crowded with plants until, in the fir forests at the highest elevations, the trees grow very close together. Many desert plants are leafless or have had their leaves reduced to spines, minimizing water loss. The sequence progresses upward to grasses, to shrubs with narrow but not needlelike leaves, to plants whose elongated, thick leaves are densely crowded at the plant base, to broad-leaved evergreen shrubs, to broad-leaved evergreen trees, and finally to needle-leaved evergreen trees.

A century ago, naturalist Clinton Hart Merriam called attention to the parallel between moving higher in elevation and higher in latitude (*see* "San Francisco Peaks, Arizona," *Natural History,* May 1988). At higher elevations, more of the plants belong to species found mainly in the northern United States and Canada, with fewer from the Southwest. For example, Sonoran species are common in the desert, while grasses from the Great Plains are found in the desert grassland. In the lowest forested areas, the species that prevail are southwestern and Madrean (from Mexico's Sierra Madre), while at higher elevations are found such northern species as harebell, lady fern, and golden corydalis.

About halfway to the top along the General Hitchcock Highway, the Forest Service has erected a large, informative sign summarizing the biological life zones that can be observed, from Lower Sonoran to Upper Sonoran to Transition to Canadian. But the astute observer will note that these communities are not completely distinct and that others may be identified. Between 6,000 and 7,000 feet, for example, a mosaic of plants with various geographic affinities is found—typical Rocky Mountain and northern species such as male fern, small-leaved pussy-toes, green pyrola, and snowberry; southwestern species, including Engelmann's prickly pear and Arizona wheatgrass; and Madrean species, among them Wilcox's barberry, powderpuff bush, sotol, alumroot, and a century plant.

As a result of erosion and other geological forces, Mount Lemmon is more isolated today than it was millions of years ago, when a continuous chain of mountains, extending from Canada to Mexico, permitted many species of plants to migrate north and south. While new Mexican and southwestern species continue to colonize the lower, drier regions of the mountain, adding to the diversity of plants, northern species are no longer able to bridge the gaps to reach the high peak. As a result, Mount Lemmon and similar isolated peaks are commonly referred to in Arizona as mountain islands.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.

The granite pinnacles of Mount Lemmon, above, lie less than twenty miles from the desert city of Tucson. Right: At a lower elevation in the Santa Catalina Mountains, flooded Sabino Creek flows past cottonwoods and Arizona sycamores.
David Muench

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At the American Museum

Margaret Mead Film and Video Festival

The Museum will celebrate the 1992 Margaret Mead Film and Video Festival from Tuesday, September 29, to Sunday, October 4. Among this year's highlights are *Mixed Feelings,* about an interracial South African couple living in a black township; *Summerhill at 70,* a current perspective on the renowned British progressive school; and *Black Harvest,* about a Papuan who invests in a New Guinea coffee plantation that fails. An advance package ticket for three weekday evenings and two weekend days of screenings can be purchased by mail for $40 ($36 for members). Daily admission is $10 ($9 for members) at the box office, which opens at 5:00 P.M. on weekdays and 10:00 A.M. on the weekend.

At a fund-raising benefit on October 2, guests can meet with film and video makers and view a special film event. Tickets are $30 ($27 for members). For a complete schedule, call (212) 769-5305.

Navaratri/Dussehra Celebration

Every year in India and in the Indian communities in the New York tri-state area, the ten-day festival known as Navaratri is celebrated. According to legend, no one was able to defeat the demon-king Mahisasura until the goddess Durga finally triumphed over him after nine nights (Navaratri). On the tenth day (Dussehra), a new era began.

During the Museum's Navaratri celebration, Saturday and Sunday, September 26 and 27, traditions and beliefs associated with this holiday of renewal will be presented from different areas of India. Highlighting the program will be performances by two of India's outstanding women artists: the dancer Lakshmi, who will perform classical dance from southern India in the *bharata natyam* style; and the singer Savita Devi, who will make her United States debut in a concert of northern Indian vocal music.

Lectures and folk dance workshops will be given, and traditional crafts will be demonstrated, including the decorating of entryways with designs made from colored rice flour and the weaving of flower garlands. The "how-to" of wearing a sari will also be shown.

Cosponsored by the Association of Indians in America, Inc., and the Museum's Education Department, these programs are made possible in part by gifts from the family of Frederick H. Leonhardt and the Samuel and May Rudin Foundation. The programs are free with admission to the Museum. For a detailed flier, call (212) 769-5315.

Astronomy in the Americas Before Columbus

On Tuesday, September 29, Anthony Aveni, a professor of astronomy and anthropology at Colgate University, will present an illustrated talk, "Skywatchers of Ancient Mexico: The Aztecs, Incas, and Mayans." He will discuss how Maya priest-astronomers observed the planet Venus and were able to calculate its motion. He will also show samples of Maya

A scene from Summerhill at 70, *to be shown at the Margaret Mead Film and Video Festival.*
Felicity Nock

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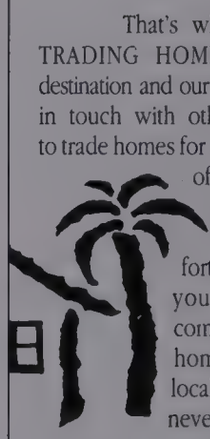

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Heading South

by Gail S. Cleere

On September 22 the sun will reach the autumnal equinox, the start of autumn in the Northern Hemisphere—when the sun, moving south in the sky, crosses the celestial equator. On this day the sun will be directly overhead at noon at the earth's equator, one of only two times during the year that this occurs. The other time is the vernal equinox, on March 20 or 21. These are also the only two times during the year when the sun rises exactly in the east and sets exactly in the west the world over (except at the poles).

Equinox, which means "equal night," implies that the day and the night are of equal length on this day. But the actual date on which the day and night are each twelve hours long, or most nearly so, is a few days before the spring equinox and a few days after the autumnal equinox and varies depending on latitude. The actual sunrise and sunset times are modified by atmospheric refraction, which bends the sun's light before it reaches us, so that the sun appears to have risen even before it has and looks like it is still above the horizon when it has already set. Astronomers define sunrise as that moment when the sun's upper edge climbs up over the eastern horizon, and sunset as when the upper edge slips below the western horizon. The times of sunrise and sunset listed in the almanacs are calculated for the normal atmospheric refraction of thirty-four minutes of arc; at these times the center of the sun is actually fifty minutes of arc below an unobstructed horizon for an observer on a level region, with no atmosphere.

Aside from these purely scientific definitions, the date of the autumnal equinox is also the date of very old harvest celebrations and traditions. The Jewish Feast of Tabernacles, called the Feast of Ingathering in the Old Testament, dates from those ancient times when huts (or tabernacles) were built in the fields for entire families to dwell in while the harvest was being gathered. Whether this was originally a Hebrew festival or was adopted from the Canaanites is uncertain. Until the late nineteenth century, the English celebrated the festival of "harvest home," when common laborer and master alike mixed freely at a feast of thanksgiving for the season's abundance. Copious amounts of cider and beer washed down goose, game, and beef, and thoughtful farmers made sure the barn was open for those who might require rest and meditation. The oldest harvester present sometimes offered a toast, which in Somerset, England, went like this:

> Here's to the health of our master,
> the founder of the feast,
> We pray to God his soul may rest
> where all is love and peace,
> While here it is our duty
> to consider his demands,
> And take it as a pleasure
> to bow to his command.

This harvest festival was always timed to occur on or around the date of the equinox and sometimes coincided with the full moon. Long after the astronomical significance of these harvest festivals was forgotten, in the midst of the Civil War in 1863, Abraham Lincoln declared our own harvest festival, naming the last Thursday in November a national day of Thanksgiving. From binding up tall sheaves of wheat to the building of evening bonfires, the rituals reach back much further than the Pilgrim stories, to a time when the motion of the stars across the sky in a comforting yearly pattern served as a calendar.

The Planets in September

Mercury is just above the bright star Regulus in Leo early on the morning of the 2d. Moving rapidly eastward, the planet reaches superior conjunction by the 15th and enters the evening sky.

Venus moves more slowly out from behind the sun but is still too close to the western horizon in the evening to be of much prominence. In the coming months,

is brilliant planet will become increasgly dominant in the evening sky.

Mars passes above the top of the magificent winter constellation Orion this nonth, moving eastward from Taurus ook for the V-shaped Hyades cluster est of the planet) and into Gemini (look or the twin stars, Castor and Pollux, to the ft—east—of the planet). Rising about idnight, ruddy Mars will be very near e last-quarter moon early in the morning n the 20th.

Jupiter slips behind the sun on the 7th, passing from the evening to the orning sky. During the rest of the year, is very bright planet will dominate the redawn scene.

Saturn can be seen low in the southeast s soon as it gets dark. This ringed planet, magnificent sight even in small telecopes, is found amid the faint stars of apricornus just five degrees south of the axing gibbous moon on the 8th and 9th.

Uranus and **Neptune** follow Sagittarus in the autumn skies, crossing your ocal southern meridian about 8:30 P.M., DT, and setting after midnight. Currently uite near each other, these two blue-green orlds inch ever closer to a wonderful onjunction, due to occur early next year. hey won't be this close again until the wenty-third century.

Pluto remains near the Serpens-Libra order, no brighter than +13.7 magnitude, bout a thousand times fainter than the aintest star that can be seen with the aked eye under ideal conditions.

The **Moon** reaches first quarter on the d at 6:39 P.M., EDT; full moon is on the 1th at 10:17 P.M., EDT; last-quarter moon ccurs on the 19th at 3:53 P.M., EDT; new noon is on the 26th at 6:40 A.M., EDT.

Gail S. Cleere writes on popular astronomy and is a founding member of the International Dark Sky Association, an organization dedicated to preserving the skies for astronomy.

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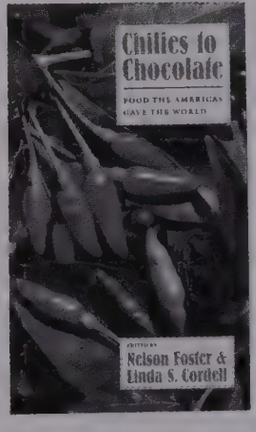

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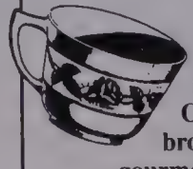

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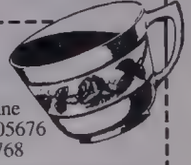

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Infrequent Flier

There's no there here either

by Roger L. Welsch

A friend of mine who knows Mel Brooks once felt obliged to tell him how awful he looked. Brooks shook his head and rolled his eyes and replied that things were not going well at all. A couple of nights before, he explained, he was in bed reading Plato and ran across a passage in which Plato reported that all men are mortal. Brooks said he hadn't been able to enjoy a cup of coffee since. Hard to imagine a more unlikely circumstance (Brooks reading Plato in bed), a more unlikely innocence (needing Plato to tell him that man is mortal), or a more unlikely consequence (a loss of joy in a cup of coffee). But realizations of one's own mortality rarely seem so funny.

I once found myself cornered into considering the uncertain nature of my existence, alive or dead. I was in Jamestown, North Dakota, for a conference. I flew into town on one day, presented my paper, and went back out to the small airport to fly home the next day. I stepped up to the ticket counter and presented my tickets. The young man behind the counter looked over my papers, poked at the computer a couple of times, handed me back my ticket envelope, looked me straight in the eye, and said, "Sorry, Sir, but your return ticket has been canceled." "Wha——bu——uh——huh?" "Since you didn't use the first half of your ticket, the second half was automatically canceled." "But I did use the first half of my ticket. I flew in yesterday morning." "No, Sir, I'm sorry but our records show you did not fly in, at least not into this airport."

Jamestown, North Dakota, is a nice place, and I wouldn't have minded staying there another day or so until I got things straightened out, but like Brooks, I was shaken by the prospect of not being. As I stood there looking at that ticket clerk, I realized that it was his contention that I was not there and it was up to me to prove that I was. I had never had to do that before, so I really wasn't prepared to face the charge: absent until proved present.

"How can I be standing here in front of you if I didn't fly in yesterday?"

"I have no idea, Sir, but you did not fly in."

"Look, here are the tags on my luggage from yesterday's flight. How could I have gotten the tags without being on that flight?"

"I have no idea, Sir."

If it's difficult to come up with a way of verifying my presence when all six foot, two inches, 270 pounds of me are standing right there, mortality and its consequences take on new importance and uncertainty. I'm not the first person who has considered this problem. Philosophers and writers have devoted lifetimes to the task. You know: Being and Nothingness; To be or not to be; *Cogito ergo sum.* (I never think of that last quotation without also thinking of a variation I once read on some newlyweds' car: "Coito ergo sum.")

What are we, really? In the Western world we seem to think that we are what we have, but once we are gone, so is all that we have, so.... Plains Indians hold that we are what we give away, but once we give it away.... The Vikings believed that what endures of a person, and therefore what is important in life, is reputation, and they may be close to right, since some of them remain with us in their reputations as reported by millennium-old sagas. Is our existence then embodied in the least tangible part of us, our reputations? Where does that idea leave us?

Not long ago, at the American Museum, I had an unpleasant recall of my Jamestown experience. I have only been in that wonderful place twice, both times to visit the office of *Natural History* magazine. The first time, I entered the Museum through the south entrance, which meant that I was only a few steps from the *Natural History* offices, but I saw enough during my short walk in and my longer stroll out that I knew I wanted to see more. So, on my second visit, I entered the Museum through the main, east door—the entrance farthest from the magazine's corner. I walked in, approached the information desk, and explained that I was on my way to *Natural History.* The woman at the desk called the editorial office to get me a pass. She handed the telephone to me so I could explain that it was going to take me some time to get there because I was taking the long way through.

The editor on the line asked me, "Are you here?"

Maybe I'm dense, but I didn't know what to say. Of course I'm here. I'm always "here." The question was not my existence or presence but the nature of "here." I took too long to answer and the person on the telephone tried again: "Are you here?"

"Uh, yeah, I'm here, I guess."

"Then it won't take you long because you're only a couple of steps down the hallway."

"No, I'm not there. I'm here."

"So you're not here?"

"No, I *am* here. But I'm at the big door in front, not the little door at the side."

"Here" is wherever I am. On the other hand, I am never "there."

The Lakota holy man Black Elk once took poet John Neihardt to the top of Harney Peak in the Black Hills to pray. Neihardt asked Black Elk why it was necessary to go to Harney Peak. Black Elk explained that Harney Peak is the center of the world. Neihardt asked Black Elk why he thought Harney Peak was the center of the earth, how he came to know such a thing. Black Elk chuckled at the white man's innocence and with studied patience explained that on a ball like the earth, every place is the center. I guess that's the way we move through this world, always in the middle of where we are.

Maybe it comes down to what the old-timer said when he first saw a steam en-

ine: "I don't know what it is, but what-ver it is, there she be." Anyway, that's the ort of unassailable logic I needed to get ut of my jam at the Jamestown airport. I tood there in front of the stern ticket clerk, trying to figure out what I could show him to document my Jamestown re-ality. My business card wouldn't do any good; anyone could have my business card. My driver's license shows only that I have a driver's license. My VISA card demonstrates that someone else believes I exist in a financially abstract sense but not necessarily that I exist right here, at the Jamestown airport, at this very moment.

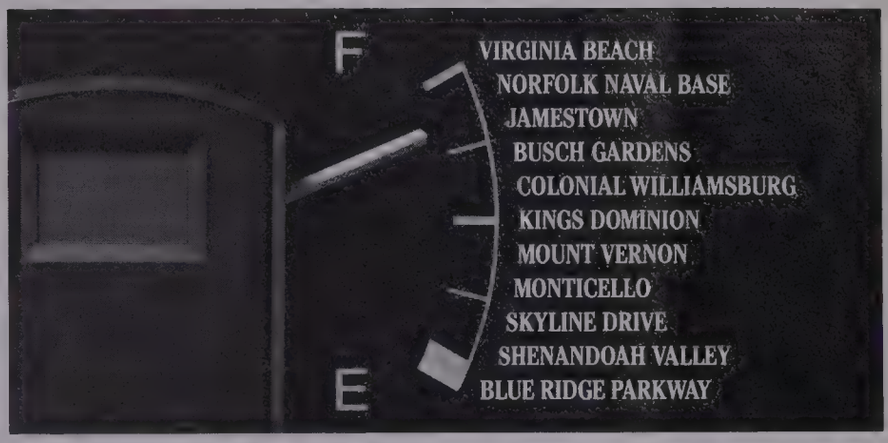
"Sir, I am going to have to ask you to move so I can help other passengers," the clerk said. I turned and saw that six or seven would-be fliers, all probably able to demonstrate their existence, were standing behind me, lined up at what was the only counter in the airport.

"Sir, can I ask you to step aside?"

And then I realized that the best proof of my existence was…my existence. "Pay no attention to me," I said. "You win. I'm not here." I had him cornered. Even if he believed I wasn't there, even if he knew I wasn't there, circumstances were increasingly requiring him to act as if I were there. And finally that's what he did. I got home that afternoon, considerably less confident than I had been the day before but considerably more confident than I had been that morning.

If I could talk with Mel Brooks, I would suggest the same course of action for him. Drink your coffee, Mel, and thereby demonstrate that at least for the moment, you are here and not there.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska. His latest book is Touching the Fire: Buffalo Dancers, the Sky Bundle, and Other Tales *(Villard Books, 1992), an exploration of rites, objects, and places sacred to Native Americans.*



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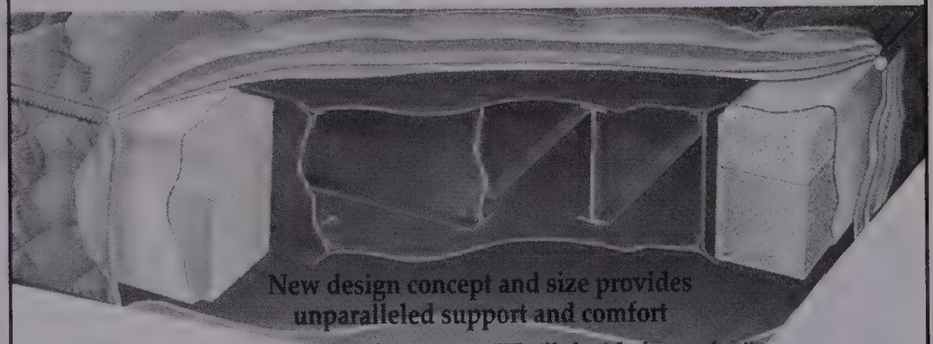

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An Aristocratic Liver

With subtle and secret breeding, a controversial French delicacy is being produced in the United States

by Raymond Sokolov

In the summer of 1962, my parents took me to lunch in the Restaurant de la Pyramide in Vienne in the Rhone region of France. It was there that Fernand Point had created the most influential kitchen of the post-World War II period. He was a fanatic apostle of the gospel preached by the gastronomic writer Curnonsky: A dish should taste of what it is. No frills, no furbelows, no masking sauces. In his crusade to preserve the natural flavors of ingredients, Point taught apprentices to fry eggs over a candle. Some of those apprentices went on to develop the Vienne master's ideas into what they came to call the nouvelle cuisine.

This grand simplification of *haute cuisine* had not yet taken hold in 1962. But in the garden of chez Point, at the age of twenty, I got an inkling of the future. My memory of what I ate is no longer complete. The most vivid emotion I can recall is fear. My father discovered that he had left his wallet in the car—cash, traveler's checks, passports—and I was sent to see if it was still there. It was.

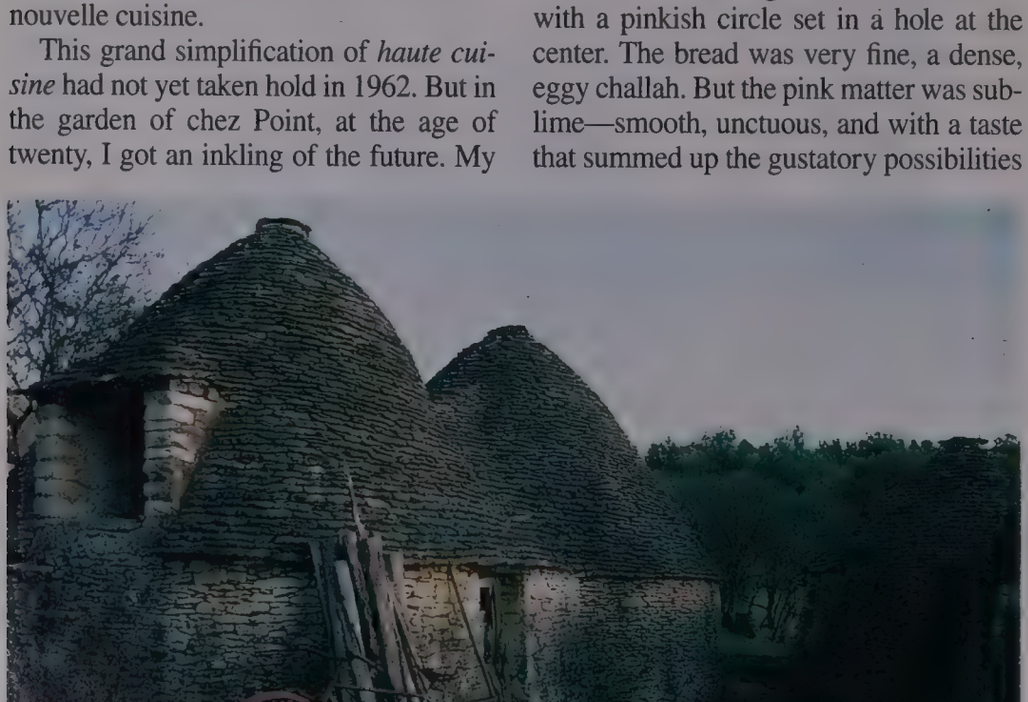
Earlier in the meal I had been equally fortunate when the waiter prevailed on us to accept a combination of first courses chosen by him. Although I'm sure we were told what each one would be, I must have misunderstood or ignored the French explanation. So these splendid hors d'oeuvres were for me a kind of blind tasting.

The best was a golden slice of bread with a pinkish circle set in a hole at the center. The bread was very fine, a dense, eggy challah. But the pink matter was sublime—smooth, unctuous, and with a taste that summed up the gustatory possibilities of red meat in its fleshy essence, with al vulgarity of blood and gristle expunged.

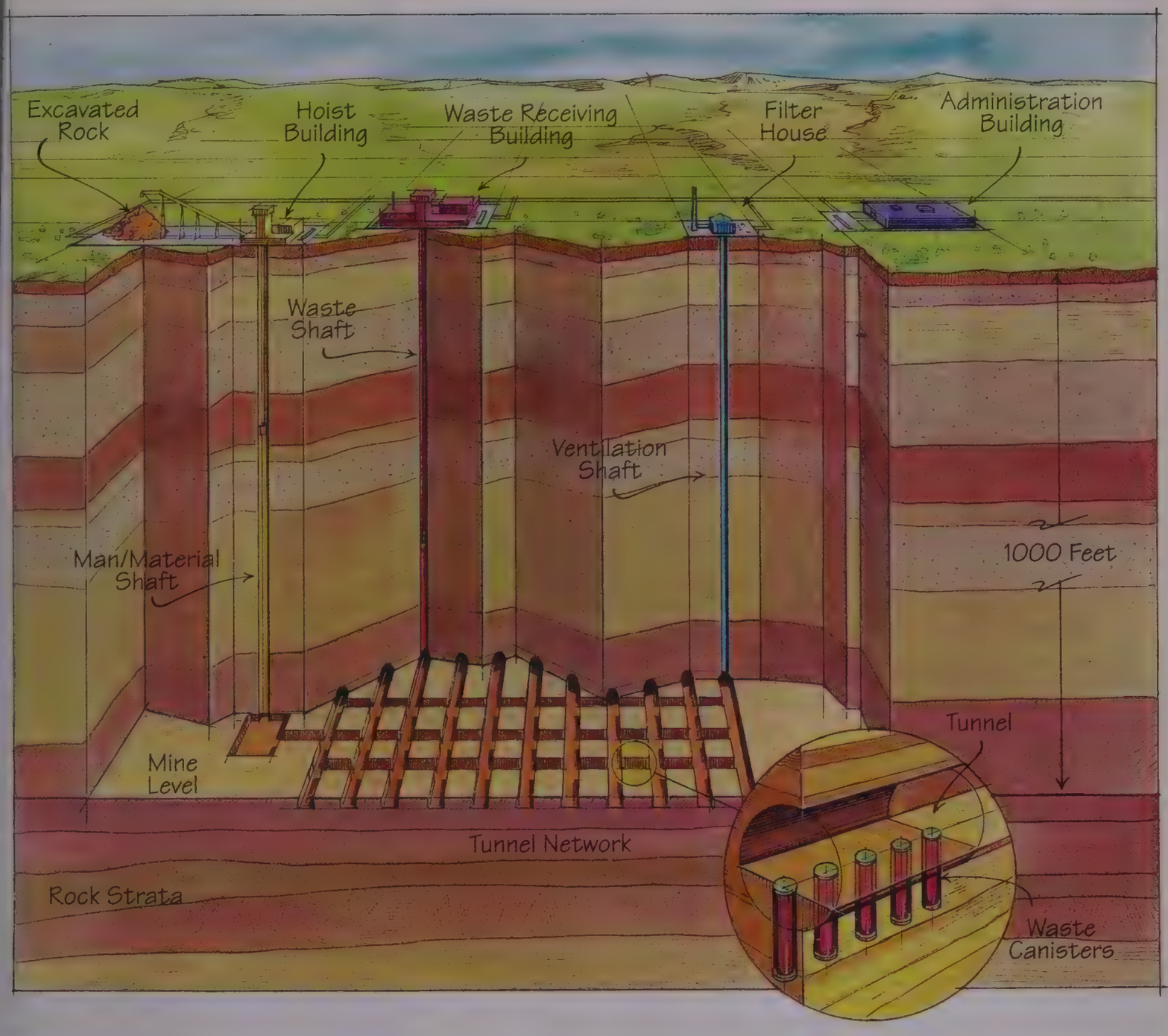
Having eaten this wonderful and alway expensive stuff a few times since, I know that we were served foie gras at Point *Foie gras en brioche*. (The brioche alone was worth three stars in Michelin and has helped me understand the fury of the French revolutionaries when they heard Marie Antoinette's reaction to the news that some of her people had no bread—*pain*. "Let them eat brioche," she said, no cake as the usual, gastronomically impre cise translation has it.)

Foie gras is, literally, fat liver. In prac tice the term refers to the oversized livers of geese or ducks fed very intensively in order to increase the weight of the organ well above the normal, to more than a pound, sometimes more than a pound and a half. The result is one of the glories of French cooking. The high cost of foie gras has effectively limited its appearance in its pure form to the tables of luxury restaurants. But in origin, it is a rustic product of simple farms, traditionally in southwest France, where housewives in the Landes district below Bordeaux deliberately overfed their geese with lots and lots of corn. According to legend, they nailed the geese's feet to the barn floor and periodically inserted a tube down their long necks. A hand-cranked auger propelled corn down the tube until the food reservoir in the animal's esophagus (the craw, or crop) was full. Over the next few hours the bird ingested the fodder, and then the tube went in again and again, until the liver had expanded to optimal size.

I can't vouch for the nailing of the feet, but I have seen the traditional instrument of stuffing, or gavage. The proprietress of the Paris restaurant Lous Landès showed



A goose near its traditional round stone hut, Aquitaine, France
Bruno Barbey; Magnum



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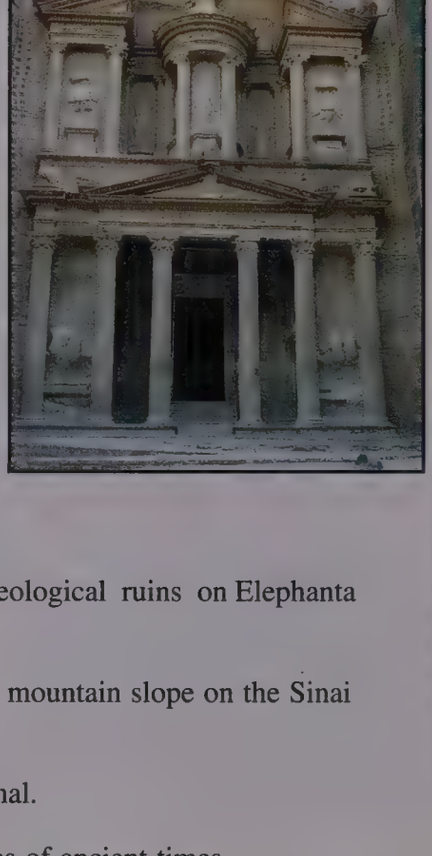

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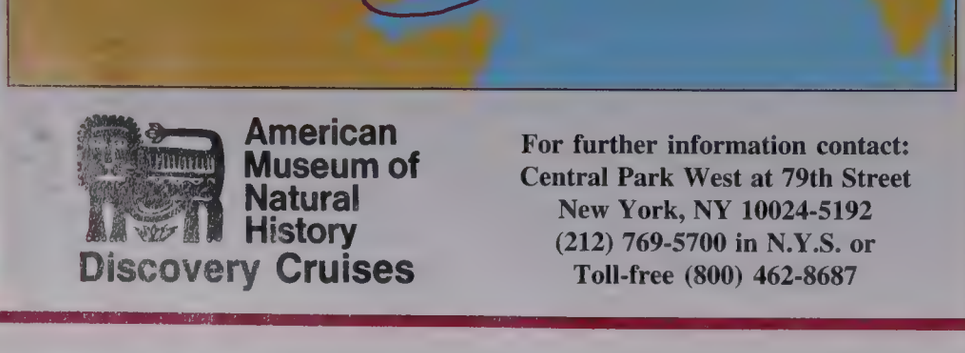

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me one in a matter-of-fact way. Then she served us some remarkable foie gras.

In this country, fresh foie gras was unobtainable until the 1980s. Before then, had always assumed that some agricultural regulation made its production illega or impossible because of American scruples about cruelty to animals. This was no the case. Like many costly exotic foodstuffs without an established market here foie gras produced by the traditiona method offered no obvious economic incentive to potential investors. And the French product (not to mention the Hungarian and Israeli foies gras that have long dominated the industry worldwide) could not be imported as raw liver because o import barriers designed to keep out the flesh of diseased animals and to protec U.S. producers against foreign competition. The best that the foie gras-aler American consumer could do was settle for a very lightly cooked foie gras tha elite restaurants, such as Lutèce in New York, brought over in lieu of the vastly superior fresh liver. For the undiscriminating, there was also an abundance o canned pâté de foie gras, often truffled adulterated in varying degrees, and alway insipid, compared with the real thing.

This situation made no sense. But a solution was brewing quietly in Israel. The first step was the invention, in that country, of a better bird. About 1974, the traditional foie gras goose was in trouble. Epidemic disease threatened the industry. I producers were to continue in the old way they faced the necessity of costly and possibly dangerous courses of vaccination and antibiotics. Instead they improvised the hybridization of the moulard duck. This black-and-white marvel of hardiness and productivity is the sterile offspring o the male of the recently domesticated redjowled Muscovy, or Barbary, duck and the female of the fecund white Pekin, a common barnyard variety. The moulard is capable of withstanding a "strong program." That is how Amnons Israel, who participated in the development of the moulard in Israel, his native country, refers to the feed regimen he gives hundreds of moulards at Specialty Game Birds of Ferndale New York, in the heart of Sullivan County's borscht belt, one of three such companies now producing foie gras in this country.

The moulards are disease resistant and will grow big livers as scrumptious and elegant as anything a French goose can manage. But their leading virtue—the secret of the moulards' success in the high-

nd liver world—is the efficiency with which they are hatched.

At the core of the moulard–foie gras usiness is a closely guarded technique of rtificial insemination. Without it, the sexally "lazy" Muscovy males, or drakes, ould not be economically viable sires, nd Muscovy hens aren't prolific egg layrs. But white Pekin hens happily supply bundant clutches of eggs containing noulard embryos if they are repeatedly ineminated with Muscovy semen.

There is nothing unusual about the artiicial insemination of poultry. The difficult art—the heart of the matter for mouards—is the extraction of semen from hose farouche Muscovy drakes. This requires careful training of the birds and, as srael puts it, a special touch. The technique is hush-hush, the one part of the foie gras production system I didn't get a full briefing on during a recent visit to Specialty Game Bird's large barn and slaughterhouse. I can say, however, that the sixty-five breeding drakes I saw looked healthy and very glad to have humans come into the room where they are caged.

For their part, the white Pekins were clean and active in the spacious pens. Their moulard offspring also looked spry and content. They eat normally for twelve weeks, taking feed as the yen comes upon them. Then, for an average of twenty-eight days, they are put through the program that is the reason for their existence. It works like this.

Each day, the moulards are fed a little more than the previous day. And each day their appetite increases. "This is not force feeding," says Israel. "They want the feed. When they stop taking it in, we stop the program."

The goal is to have each duck consume thirty-three pounds of the pelletized high-protein feed. Only in the last week of the program does the liver expand into a foie gras. In every one of those seven days, the moulard adds 7.6 ounces to the weight of its liver.

All this while, the moulards are living fourteen to a cage, moving freely in a space far more ample than battery chickens enjoy. Every eight hours an attendant comes and inserts the moistened stainless steel tube of a funnel. A motorized augur substitutes for the hand crank of tradition. Israel insists the birds feel no pain. He is surely right that it is natural for them to hold food in their esophagus during their relatively protracted digestion period. And if the pellets actually do stick in the bird's craw, the program stops and the bird goes

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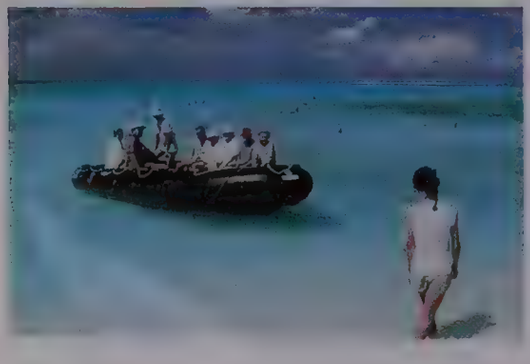

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to be slaughtered in the presence of a U.S. Department of Agriculture inspector. Specialty Game Birds uses the kosher method of slaughter—slitting the throat—not out of religious conviction but because, Israel believes, the animal loses consciousness immediately while the heart continues to beat long enough to pump residual blood through the liver, leaving it purged and clean.

Recently, animal rights activists infiltrated one of their members into another Sullivan County foie gras company. Pictures were taken, local law enforcement was invited to take action, and articles were written in the local press and eventually in the *New York Times*. In the end, no legal action was taken, and the scientific community, including veterinarians and a poultry scientist, defended the foie gras producer. But the controversy remains, because some people will always find foie gras an unnecessary, repellent, and possibly cruel exploitation of animals.

Many animal husbandry practices are open to such charges. Foie gras simply offers a dramatic focus for such feelings, not because its manufacture is vicious, but because it is artificial, and even more so because it includes intervarietal artificial insemination.

A symbol of luxury and rarely cooked by nonprofessionals, foie gras, even in great restaurants, rarely ends up as anything more than plain liver served with minimal garnishing. The ingredient is so perfect and so expensive (about $40 a pound) that it almost always achieves Curnonsky's ideal. Like other aristocrats it can afford to be itself.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

Terrine of Foie Gras

(Based on information and a recipe in *Foie Gras, Magret, and Other Good Food from Gascony,* by Andre Daguin and Anne de Ravel, Random House, 1988)

1 whole fresh (raw) duck foie gras, 1 to 1½ pounds, at room temperature
Salt
White pepper, freshly crushed

1. Preheat oven to 200 degrees.
2. Bring a large pot of salted water to a boil.
3. Carefully examine the liver. It has two lobes, one larger than the other. Peel off any of the translucent membrane that may be left on the outside. Gently pull apart the two lobes. Remove any green bile spots in their internal folds with a knife. With a finger, gently probe the internal folds and pull out the vein system in each lobe.
4. Put the lobes in the boiling water and blanch for two minutes. Drain, pat dry with paper towel, and season liberally all over with salt and pepper.
5. Line a 5-cup terrine mold or a 5-cup square stainless steel cake mold with plastic wrap so that there is a 5-inch overhang on all sides. Place the foie gras in the mold and fold the wrap over the mold.
6. Cover the bottom of a deep ovenproof pan slightly larger than the terrine mold or cake mold with six layers of paper towel. Cover the terrine or cake mold (for the cake mold or for a terrine whose cover has a handle use a piece of cardboard cut to fit tightly inside the mold) and set it on the paper towel. Set the pan in the oven and cook for approximately 40 minutes or until the internal temperature of the liver is 115 degrees (measured with a meat thermometer).
7. Set the terrine or cake mold in a pan of ice water. Reverse the terrine cover (if it has no handle) to increase pressure on the liver, or weight the cardboard with several heavy cans. This forces fat out of the liver. When the liver is completely covered with fat, remove the cardboard, cover tightly, and refrigerate for two to three days before serving. The liver will keep for up to three weeks if kept refrigerated under a layer of fat.
8. To serve, remove the fat from the surface, unmold, and cut into serving slices.

Yield: 7 to 10 servings

Liberty Potatoes

Reserved fat from 1 foie gras terrine
6 medium potatoes, peeled and sliced
Salt

1. Melt the fat.
2. Fry the potato slices, a handful at a time, until nicely browned. Drain each batch and keep warm. Continue with successive batches until done. Salt to taste.

Yield: 4 to 6 servings

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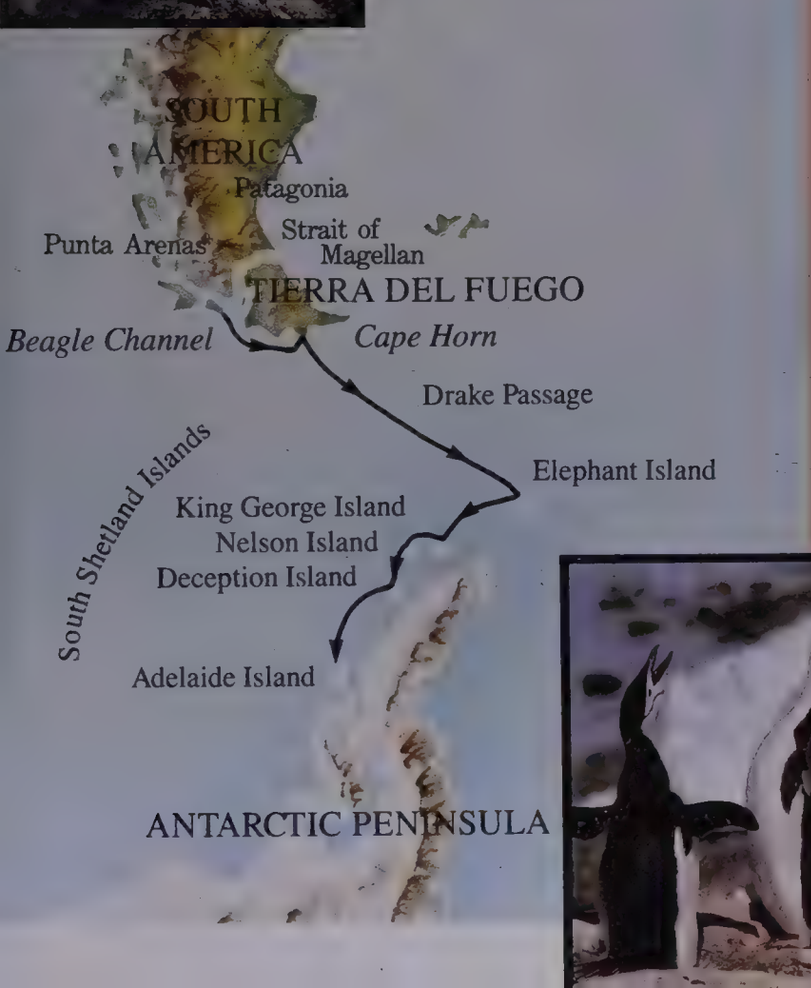

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Found primarily in saltwater lagoons from the Gulf Coast of the United States to Central America, reddish egrets were nearly wiped out in the 1880s by hunters who slaughtered them and other herons for plumes to adorn women's hats. Ironically, the species may have survived the

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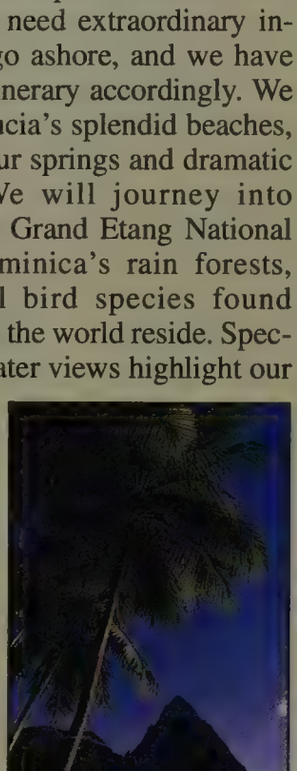

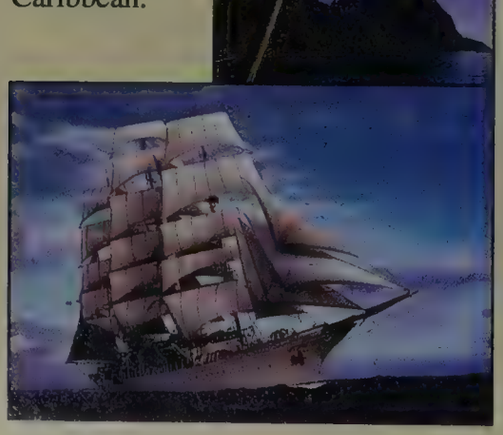

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China's Taklimakan Desert may seem an inhospitable place for an archeological venture, but **John W. Olsen** (page 30) is gambling that in the dim past, early humans passed that way and left their traces. He is also drawn to the region for the lessons it can offer in the causes and consequences of desertification. An associate professor of anthropology at the University of Arizona, Olsen has resided in China

on several occasions, most recently in 1990–91 as director of the U.S. National Academy of Sciences Beijing office. Currently, he is a Fulbright lecturer at Kazakh State University in Alma Ata, Kazakhstan. For additional reading, he recommends *The Archaeology of Ancient China,* by Kwang-Chih Chang (New Haven: Yale University Press, 1987); *Foreign Devils on the Silk Road: The Search for the Lost Cities and Treasures of Chinese Central Asia,* by Peter Hopkirk (Amherst: University of Massachusetts Press, 1984); *The Silk Road,* by Irene M. Franck and David M. Brownstone (New York: Facts on File, 1986); and Owen Lattimore's 1929 book *The Desert Road to Turkestan* (New York: AMS Press, reprinted in 1975).

Paleontologist **Judy A. Massare** (pa 48) decided to specialize in the study extinct marine reptiles when she was graduate student at Johns Hopkins Unive sity in Baltimore, where she received h doctorate in 1983. "Of all the marine re tile groups," Massare says, "I find the ic thyosaurs the most interesting becau they are so highly modified for mari life." Her investigations into tooth shap and the biomechanical aspects of swir ming in ichthyosaurs have led her to ne insights on ichthyosaur evolution and na ural history. A former assistant profess of geological sciences at the University Rochester, Massare now teaches earth sc ence at the State University of New Yo College at Brockport. She has done fiel

At the Archbold Biological Station Lake Placid, Florida, **Samuel D. Ma shall** (page 40) posed with a scrub jay his shoulder. Although Marshall remai interested in birds (having once worked the Department of Ornithology at th Bronx Zoo), his favorite members of th animal kingdom have always been sp ders, particularly tarantulas. In the a knowledgments accompanying his late publication in the *Journal of Arachnolog* he wrote, "The senior author especial wishes to thank the Marshall family f their support and toleration of a *Ther phosa* colony in their basement during th early stages of his tarantula studies." Soo after seeing his first tarantula at age fou teen, Marshall kept about 100 of the larg hairy spiders in the basement of his hom in upstate New York. He claims that on one escaped, and it never made it upstair His fieldwork on tarantulas has taken hi to French Guiana, Venezuela, Ecuado and Arizona. Marshall is currently worl ing on his Ph.D. at the University of Te nessee, focusing on the territorial behavi of burrowing wolf spiders. For furth reading on tarantulas, he recommend Willis Gertsch's *American Spiders* (Ne York: Van Nostrand Reinhold, 1979).

ork in Wyoming, Idaho, and Nevada—
e relatively ichthyosaur-rich areas of
orth America. At the Berlin Ichthyosaur
ate Park in Austen, Nevada, she helped
cavate the remains of a *Shonisaurus,* the
ant ichthyosaur of the Triassic period.
or more information, Massare recom-
ends *Dinosaurs, Spitfires, and Sea*
ragons, by Christopher McGowan
Cambridge: Harvard University Press,
991). Marine reptiles are also included in
avid Norman's *The Illustrated Encyclo-*
edia of Dinosaurs (New York: Crescent
ooks, 1985) and in *The Macmillan Illus-*
ated Encyclopedia of Dinosaurs and
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arry Cox, R. J. G. Savage, and Brian
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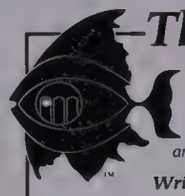

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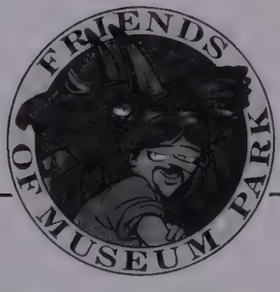

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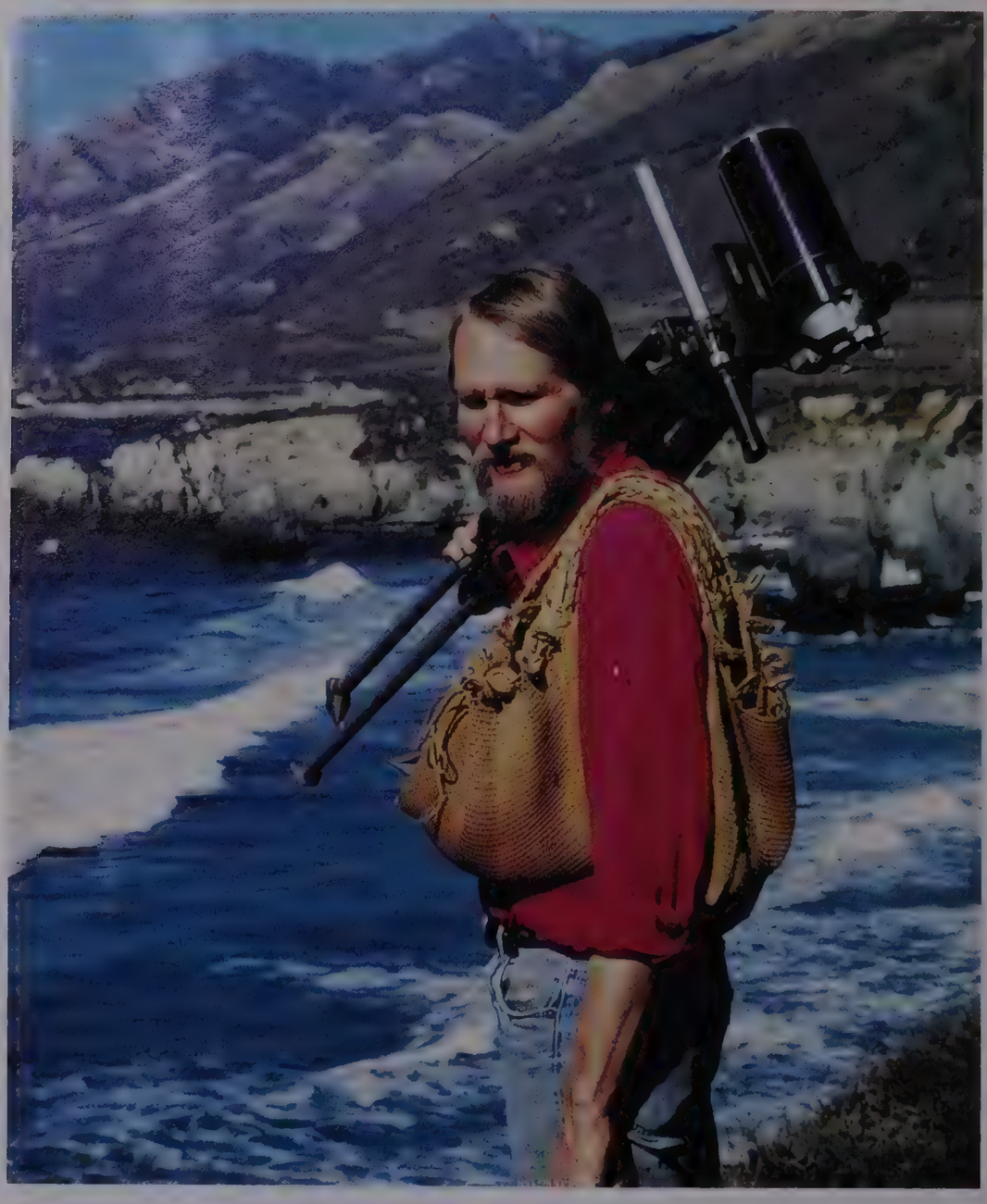

After graduating from college in t mid-1960s, **Galen B. Rathbun** (pa 54) traveled from California to Keny where he spent the next four years the U.S. Peace Corps. At the end of h tour, he undertook graduate studies the University of Nairobi, from whi he earned a Ph.D. in zoology in 197 His field research was on elephar shrews. Back in California now, Rat bun works for the U.S. Fish and Wil life Service in San Simeon, where h is a research biologist and proje leader for one of the service's resear programs on endangered species in t Pacific states. He is studying the b havioral ecology of sea otters reintr duced from central California to t Channel Islands, as well as the stat and life history of declining reptil and amphibians in central and sout ern California. Rathbun hopes to r turn to East Africa to determine t status of some of the forest-dwellin elephant-shrews. For more on the little mammals, about which little h been published, he suggests his ov 1979 article, "The Social Structu and Ecology of Elephant-shrew (*Advances in Ethology,* supplement the *Journal of Comparative Etholog* vol. 20, pp. 1–77), and an article by Lumpkin, "The Elephant-shrew…l a Nose!" (*Zoogoer,* 1986), which w based on a colony that Rathbun esta lished at the National Zoological Pa in Washington, D.C.

Bradford Winn (page 84) got his photo opportunity for this month's "Natural Moment" as he lay on his belly on the beach watching herons and egrets feeding. Just as the sun rose above the trees, a reddish egret rushed by and stopped suddenly—right in front of Winn and his camera. Winn, who has been interested in birds for as long as he can remember, and who has been photographing them since he was eleven, works as an ornithologist at the New York Zoological Society's rare animal breeding and research facility on Saint Catherines Island, Georgia. He spends much of his free time photographing the wildlife of coastal Georgia and is working on a film about wetland habitats. He photographed the reddish egret with a Canon F1 camera and a 400mm lens with a 2x converter.

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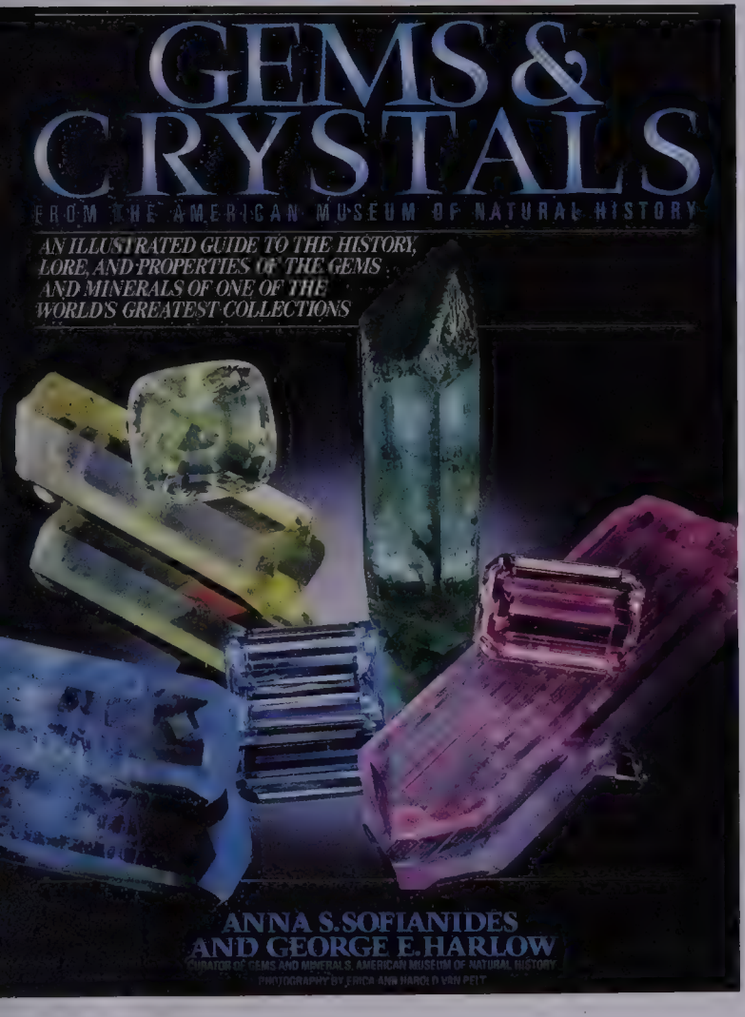
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VOL. 101, NO. 10, OCTOBER 1992

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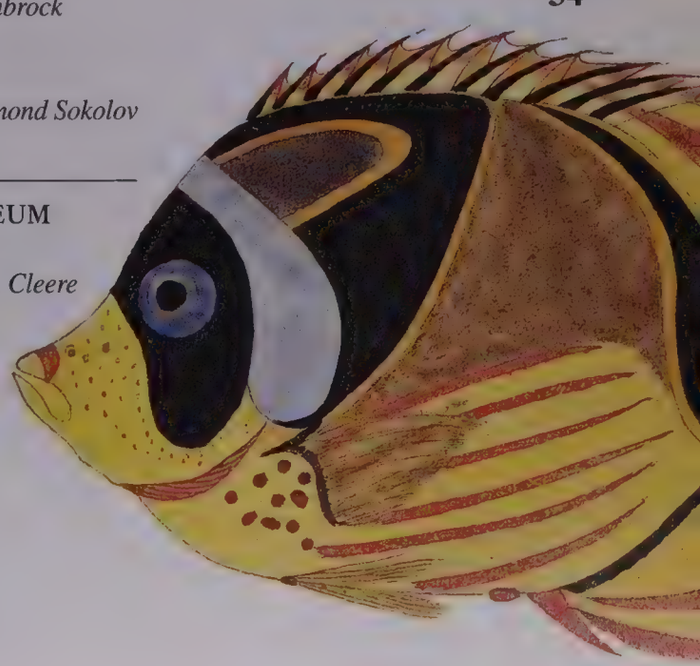

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Columbus's Comedown

"Where is my tenth, my eighth, my third?"

by Samuel M. Wilson

The Columbus of popular mythology died destitute and alone. In fact, he died a wealthy man, with his children at his bedside. Wherever he went in his last two years he was able to rent a nice house, full of servants. Near his chair he kept a small box of gold coins, which, had he been a different person, might have served to remind him that he had done pretty well for having been born a Genoese weaver's son. Instead, it acted as a painful reminder of all the things he thought he was owed, and all that had been taken from him.

Before his first voyage, Columbus had been summoned to the royal camp at Santa Fé, from which King Ferdinand and Queen Isabella were directing the siege of Grenada, the last Moorish stronghold in Spain. There Columbus was granted permission to set out across the Atlantic, and with representatives of the Crown, he drew up a document called the Capitulaciones (agreements) of Santa Fé. Even in the fifteenth century, lawyers managed to make legal documents overly long, yet obscure, but this agreement clearly contained a number of items that offered Columbus and his heirs great rewards. Juan de Coloma, a senior official of the Spanish court, negotiated the terms and notarized each agreement for the king and queen (and probably regretted it later). The first two parts dealt with Columbus's title of Admiral of the Ocean Sea and his titles on any land he might find, viceroy and governor general:

Your Highnesses appoint Don Cristó
Colón to be your Admiral in all those
lands and mainlands which by his activ
and industry shall be discovered or acqui
in the Ocean Sea, during his lifetime, a
likewise, after his death, his heirs and s
cessors one after another in perpetuity.
Likewise, that Your Highnesses appoint
said Don Cristóbal Colón to be yo
Viceroy and Governor General in all
said islands and mainlands.

The third part dealt with Columbu
share of the profits:

Item, that of all and every kind of mercha
dise, whether pearls, precious stones, go
silver, spices, and other objects and m
chandise whatsoever, of whatever kin
name and sort, which may be boug
bartered, discovered, acquired and obtain
within the limits of the said Admiralty, Yo
Highnesses grant from now henceforth
the said Don Cristóbal, and will that he m
have and take for himself, the tenth part
the whole, after deducting all the expens
which may be incurred therein, so that
what part shall remain clear and free he m
have and take the tenth part for himself, a
may do therewith as he pleases, the oth
nine parts being reserved for Your Hig
nesses.

The fourth part dealt with protecti
Columbus from lawsuits, and the fi
stated that "the said Don Cristóbal Col
may, if he chooses, contribute and pay t
eighth part of all that may be spent in t
equipment [of voyages by others], and th
likewise he may have and take the eigh
part of the profits that may result fro

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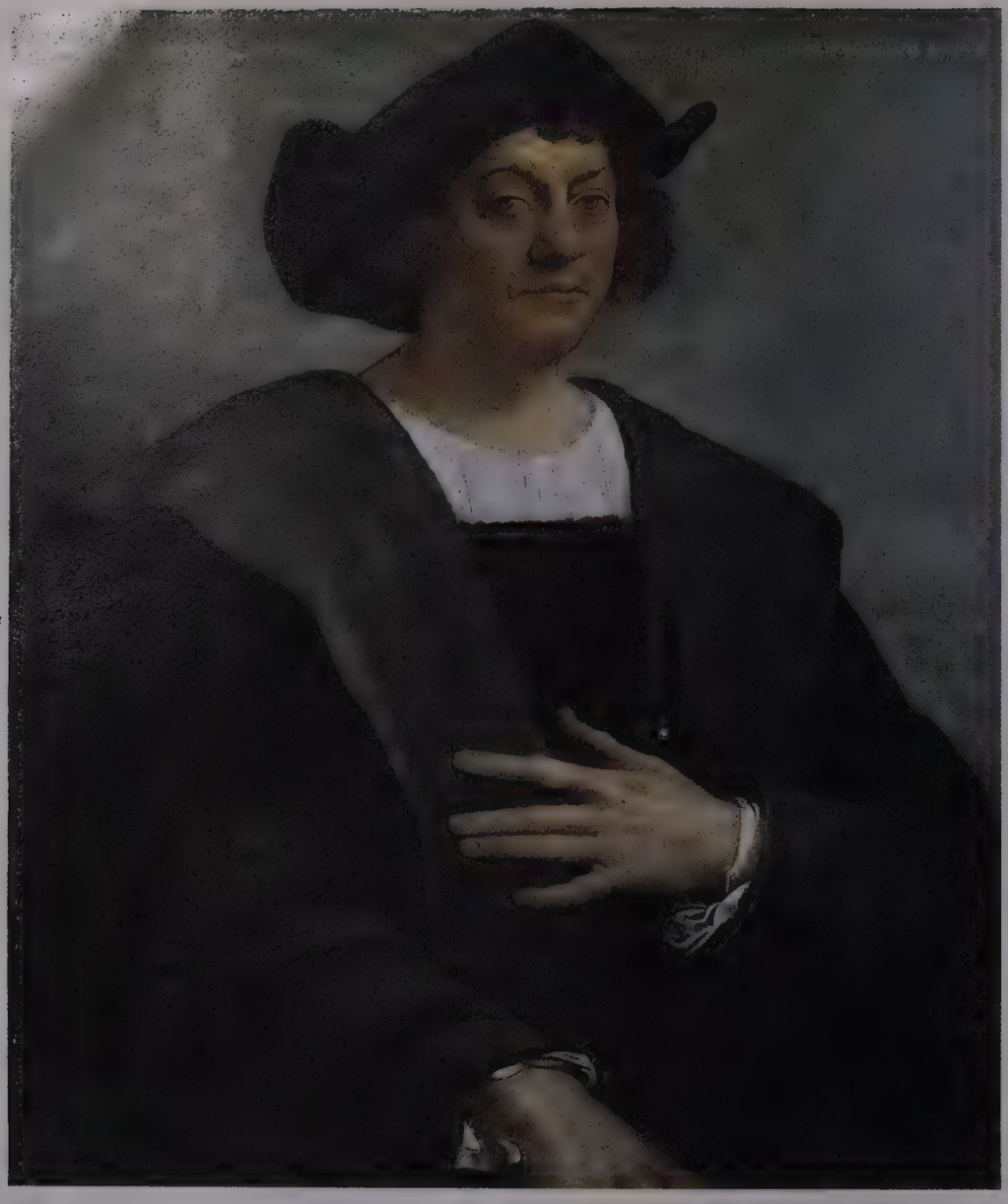

Portrait of Columbus, by Sebastiano del Piombo (1485–1547)
The Metropolitan Museum of Art. Gift of J. Pierpont Morgan, 1900

such equipment.—It so pleases their Highnesses. Juan de Coloma." (Translated by John Noble Wilford in *The Mysterious History of Columbus,* 1991.)

Columbus lost most of the concessions named in the Capitulaciones between their signing on April 17, 1492, and his death fourteen years later. The discovery of gold-producing islands, and the ever increasing prospects of other undiscovered territories in the Americas, outweighed both legal and moral restraints (certainly little of either was shown the people who had lived in these lands for ten millennia).

One by one Columbus's claims to the wealth being taken from the Americas slipped away. The "tenth" of everything soon became a tenth of the Crown's "royal fifth"—in other words 2 percent rather than 10 percent (still a fortune). The "eighth," his legitimate part of the profits of any voyage that he invested in, was very slow to arrive, if it ever did. As Columbus's health failed and he lost favor with the king, his partners in these voyages stalled on their payments.

Columbus also lost the titles of viceroy and governor general, proving himself a disaster as a leader. Columbus used people as tools, bullied and cheated them, and from the first voyage there was no shortage of people who hated him. Columbus even went back on his promise to give a decent lifelong pension to the first sailor who saw land on the first voyage: in the early morning of October 12, 1492, Rodrigo de Triana saw the island of San Salvador (Guanahani), but once it became clear that it was land, Columbus remembered that in fact he had seen land some hours before.

Even Columbus's supporter, the priest and historian Bartolomé de Las Casas, had to concede that the Columbus family, and the Admiral of the Ocean Sea in particular, "did not show modesty and discretion in governing Spaniards which they shoul have done." A foreigner—not even a aristocratic foreigner—treated Spanis gentlemen like they were servants. Co lumbus's brief reign as leader of the Span ish forces in the Indies was marked b mutiny and rebellion. What he did to th indigenous people he met in the Ne World was even worse.

In 1500, under orders from the Crown Francisco de Bobadilla sailed to Hispan iola, took over the government, and a rested Columbus (then on his third voy age). Columbus was put in irons and sen back to Spain. As far as the Spanish gov ernment was concerned, this took care o his claim to being viceroy and governo general of the Indies. The Genoese Co lumbus had once again become a for eigner in the land. Although he and his de scendants continued to battle in the court they had little legal recourse against th Crown.

Columbus was not yet out of busines however. Between 1500 and 1502 he de uged the court, mostly the queen, with le ters concerning a long-held obsession o his—capturing Jerusalem and the sepu cher of Christ, then under Islamic contro Historian Felipe Fernández-Armesto, i his splendid book *Columbus* (1991), finc that Columbus gave three arguments sup porting his dream: first, the Holy Spir had told him to do it, and in support of th he cited the many ways in which he ha been given divine help in the past; secon success would be certain if the king an queen and their subjects had faith in Go (and, Columbus believed, they did); f nally, both scriptural prophecies and astro logical predictions—"signs in the heav ens"—indicated that victory was certain As Fernández-Armesto points out, thes prophecies and predictions had to do wit the coming end of the world, a prospec that haunted Columbus.

Largely to get rid of Columbus, hopin that at last he would perish at sea, Ferd nand and Isabella gave him leave to mak one more trip to the Indies. Columbus se out with four small ships; financing wa easy to come by in this period of grea promise, but he put up some of his ow money for the venture. The king an queen expressly forbade him to go to His paniola (except perhaps for a stop on th way back), but completely in character, h headed there first.

When he reached Santo Domingo Spain's principal port in the Indies, Co lumbus was refused anchorage, so h stayed at sea off the southern coast of His

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...while he tried to negotiate with the ... commander. Soon Columbus began to observe changes in the winds, clouds, and tides that were like those he had seen in previous brushes with hurricanes. He prepared his ships for the storm and sent word to Santo Domingo advising captains not to leave port. Despite Columbus's warning, a treasure fleet of about twenty-six vessels set sail for Spain. Columbus's four ships managed to survive the hurricane intact, but the treasure fleet lost twenty ships and more than 500 lives, among them were Bobadilla and the courageous Taíno chief Guarionex (*see* "Columbus, My Enemy," *Natural History,* December 1990).

Columbus then toured the coast of Central America, where he had to abandon two of his ships. They had been turned into unseaworthy sponges by the borers that feasted on their wood hulls. The other two ships, the *Capitana* and the *Santiago,* were nearly as bad off. They barely made it to Jamaica, and on June 25, 1503, just before they sank, Columbus had them run onto a sand bar in Saint Ann's Bay. The hulks were roped together and turned into swampy living quarters for the disgusted and demoralized crew (an archeological team from Texas A&M University is currently searching for the wrecks' remains).

On July 7, 1503, more than ten years after he had landed in the Caribbean for the first time, Columbus wrote to the Spanish king and queen:

> I came to serve Your Highnesses at the age of twenty-eight, and now I have no hair upon me that is not white, and my body is infirm and exhausted. All that was left to me and to my brothers has been taken away and sold, even to the cloak that I wore, to my great dishonor.... Until now, I have wept for others; now may the skies have pity on me, and may the earth weep for me. Of things material I have not even a penny to give the Church; in things spiritual, here in the Indies, I have been separated from any form of Catholic life. Isolated in this pain, sick, expecting death every day, surrounded by a host of cruel savages and our enemies, and thus separated from the holy sacraments of holy Church, how neglected will be this soul if here it parts from my body. Weep for me, whoever has charity, truth and justice. I did not come on this voyage to navigate for gain, honor or wealth; this is certain, for any hope I had of such things is dead. I came to Your Highnesses with honest purpose and sincere zeal, and I do not lie. I humbly beg your Highnesses that, if God sees fit to remove me from this place, you will aid me to go to Rome and on other pilgrimages. You whose lives and high state the Sacred Trinity guards and increases.

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Half the company mutinied after a fe... months and wandered the northeaste... coast of Jamaica, preying on the Taíno I... dians who lived there. Columbus se... Diego Méndez de Salcedo to Hispanio... in a Taíno canoe with hired paddlers to g... a ship to rescue him, but it was nearly ... year in coming. Columbus and his cre... (including those who had mutinied) the... jammed themselves into a decrepit shi... smaller than any of the four caravels the... had begun the voyage with, and someho... made it back to Hispaniola and then ... Spain.

The disastrous fourth voyage ruine... any chance Columbus had of ever retur... ing to the Indies or of ever regaining h... title of viceroy. It demonstrated that ... was washed up as an explorer and agent ... the king, and it finished the job of wrec... ing his health.

The king and queen were probably n... thrilled to see Columbus return. Th... queen, who at many critical points ha... supported Columbus, was gravely ill an... died less than a month after his retur... Columbus had been stripped of all of h... titles except that of admiral, and he was ... poor health and increasingly desperate. ... every letter to the king he included th... same refrain: "where is my tenth, m... eighth, my third?" The "third" in th... litany was a strange figment of his imag... nation and a symptom of his increasing... irrational state of mind. Earlier admirals ... Spain's then-small island domains in th... Mediterranean, having paid for the col... nization and development of the island... themselves, had kept a third of all profit... much the way a feudal lord got a large c... of his estate's produce. In his mind... Columbus twisted this inapplicable prec... dent to mean that he should get a third ... the proceeds of the Indies—not the 2 pe... cent he in fact received, nor the 10 percen... he demanded, nor the 20 percent the Span... ish government got, but 33 percent fo... himself and his descendants forevermore.

For months on end the king ignore... Columbus, not answering his letters ... asking him to visit the court. This was a... exquisite form of torture for a person lik... Columbus, who hated to wait for anythin... but had spent his whole life in excruciatin... delays, broken by brief and usually calam... itous flurries of activity. Before his fir... voyage the king had kept him sitting an... waiting for ten years for a license to sa... west, turning the matter over to committe... after committee or otherwise puttin... Columbus on hold. When Columbus wa... deposed as viceroy of Hispaniola in 150...

Fergie on a rock

—*by*—

Ann Crump, painter

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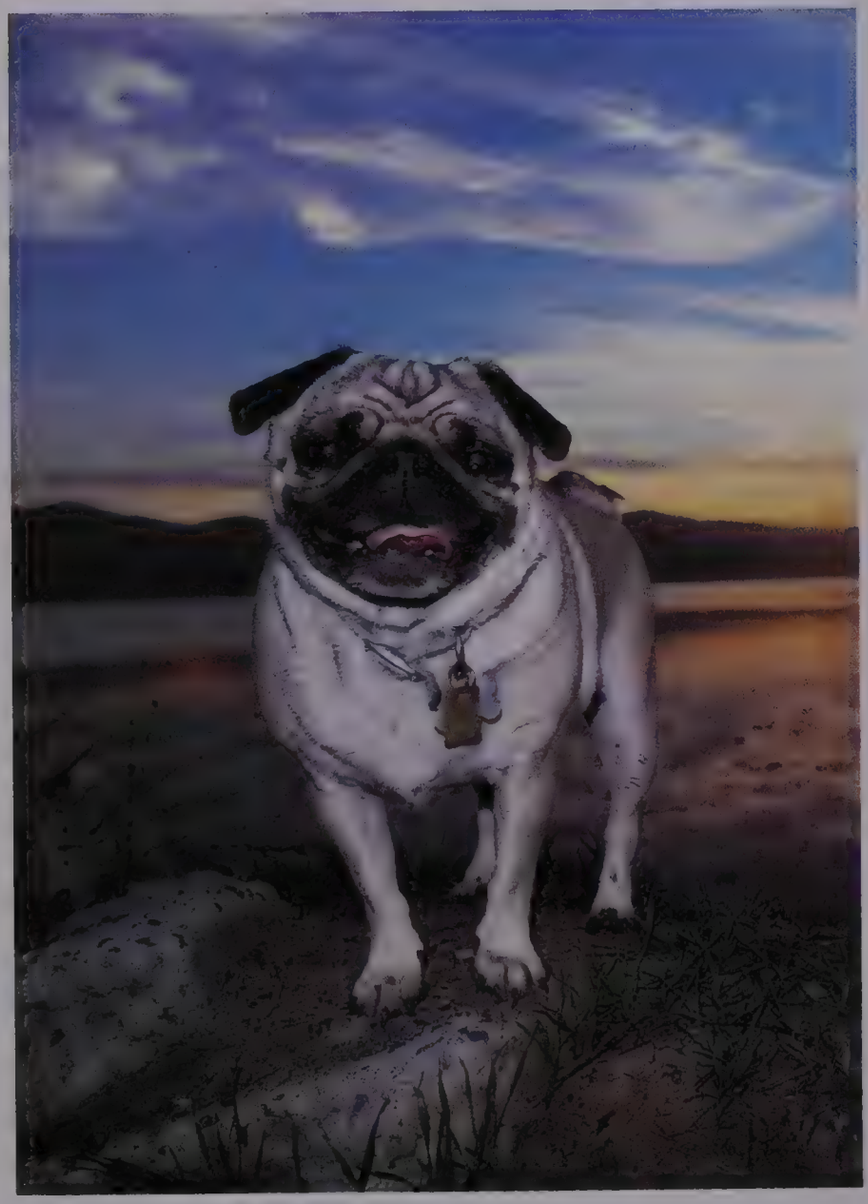

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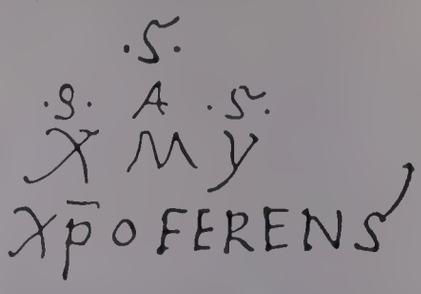
and sent back to Spain in chains (he refused the captain's offer to remove them), the king and queen had let him sit (still in chains) for six weeks after his arrival in Spain.

Of all the periods of inactivity he was forced to endure, this final one was the most agonizing of all, because Columbus, King Ferdinand, and everyone else knew that Columbus did not have many months to live. Soon, Columbus knew, his arthritic and gout-ridden body would fail him, and it would be too late. And Ferdinand knew that soon he would be rid of this annoying foreigner forever, this lowly born and overly successful pest whom he had come to genuinely loathe over the years.

Columbus sought comfort from his children, whom he manipulated and used but certainly seemed to love. Some of his last letters to Diego, his son and heir (born to his wife, Doña Felipa Perestrello e Monis, who had died young), contain moving pleas for the respect or at least love of his child. These letters all began, "My very dear son," and ended "Your father, who loves you more than himself." The relationship of Columbus and Diego was troubled, however, because Diego had what Columbus wanted most—the ear of the king. Diego had been in the queen's guard at court, and after her death in 1504, he had become part of the king's inner circle. So these letters between Columbus and Diego are torn by the admiral's love for his son and his urgent wish that Diego press his compulsive and unrealistic demands on the king.

Columbus's letter of December 1, 1504, following another written three days earlier, begins: "My very dear Son: After I received your letter of November 15th, nothing more has been heard from you. I wish you would send me some small message. Every hour I hope to receive a letter from you." He rambles on about financial problems, asking for information about the king's state of mind on this and that matter, mentioning again "the third and the tenth," and complaining that he had "not received the tenth, except the tenth of what Their Highnesses receive." At the end he reminds his son to write, adding, as subtly as an unsubtle man was able, a hint suggesting that Diego could send word if he wanted to: "Every day messengers from where you are arrive here." The letter closes: "Our Lord help you in your sacred duty. Done in Seville on the 1st of December. Your father who loves you more than himself."

Columbus signed as always with his formal signature, a cryptic stack of letters that he asked his heirs to use as their own but never really explained:



Although his meaning for the first three lines probably will never be precisely known, historian Samuel Eliot Morison believed the simplest answer is that they correspond to the Latin formula *Servus Sum Altissimi Salvatoris*—"Servant I am of the Highest Saviour," with the third line representing Christ, Mary, and Jesus, or perhaps Joseph. But the signature may be read up and down as well as across, and according to some scholars, it contains complex references to the North Star, Santiago, the Christian cross, and a ship's mast. The last line in the signature expresses the view Columbus promoted of himself in his last letter: Xp̃o is a Greek-like rendition of Cristóbal and also Christ, and FERENS means "carrier," referring to the Christ bearer. Columbus thought he was destined to expand Christendom, chosen specifically by God to do what he had done. In the last months he sometimes slipped and spoke of the New World as he conceived of it—"the Indies, which God has given to me."

As Columbus neared death, he tried to stop his pathetic and ineffectual struggling. He wrote to Diego de Garza, a sometimes sympathetic friend and eventually the archbishop of Seville, saying:

> Since it appears that His Highness does not intend to comply with the promise he made me by his spoken word and in writing, together with the Queen who now is in heaven, I think that my carrying on this fight, being only a simple laborer, would be like sailing into the wind; it would be well for me to leave this to God our Lord. He has always helped me and looked after my needs.

Death, his destiny, and the deeds of his enemies preoccupied Columbus. In his notes, he wrote down biblical prophecies and connections of his experiences with lists of biblical passages, and in the margin wrote a long and complex poem. The poem was in Spanish but at the beginning of each verse was a Latin phrase; when the Latin phrases from the six verses are combined they spell out a message: "Be mindful of thy most recent actions and thou shalt avoid sin in eternity." The last verse of Columbus's poem, in the artful translation of Felipe Fernández-Armesto, reads:

> Sinless be, and contemplate
> The agonies of those who die,
> How grief and terror are the fate
> Of sinners in their wretched state.
> Think well, as far as in thee lie,
> Upon the just, released at last
> From travails suffered in the past,
> Into the light eternally.

On March 20, 1506, at the age of fifty-five, Columbus died. Around him were his sons, Diego and Fernando; his brother Bartolomé and Diego; and a few servants and supporters. His last words are said to have been "in manus tuas, Domine, commendo spiritum meum" (into your hands, Lord, I commend my spirit)—but deathbed scenes are never quite so sanctary and romantic as those writing later make them out to be.

What gold Columbus had accumulated dissipated in two generations. (Although Diego married extremely well and linked the Columbus name with an established and powerful aristocratic lineage that endured, his son Luis traded any claim to the profits from the New World for a much smaller title and fiefdom than those Columbus was offered, and then he squandered them.) The grandiose promises the king and queen of Spain drew up before his first voyage with such an unlikely prospect as the Italian Cristoforo Colombo were one by one bought off or nullified in the interest of national security. The Crown wrote this awkward association off to experience and never made the same mistake again.

Today, Cristóbal Colón, the linear descendant of the sailor who ran into the West Indies on the way to the East Indies and never knew the difference, is a lieutenant commander in the Spanish Navy Air Corps. With commendable patience and grace, he has weathered the misplaced adulation and indignities of being a tangible symbol of so many complicated things, for he has about as much in common with his ancestor as any of us has. Yet on his business card, in small letters, beneath his name, above his telephone, telex and fax numbers, is the title Columbus fought the hardest to keep in his family forever: *Almirante del Mar Océano*. Admiral of the Ocean Sea.

Samuel M. Wilson teaches anthropology at the University of Texas at Austin.

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L E N O X . S I N C E 1 8 8 9 .

Life in a Punctuation

A visitor to Russia reflects on change in nature and the nature of change

by Stephen Jay Gould

We usually view textbooks as recorders and repositories, rather than active builders and definers of a field. But a few become so influential, and so dominating in their multiple editions, that they solidify both the commitments and the directions of a profession. Paul Samuelson's introductory textbook of economics has so performed for this half of our century, but even Samuelson cannot match the influence of his English predecessor Alfred Marshall, who first published his *Principles of Economics* in 1890. This text ran through twenty-four editions and dominated the field to the days of Marshall's greatest student, John Maynard Keynes.

Marshall stated his primary commitment in as up-front a manner as possible—and I mean literally—for he emblazoned his motto right on the title page: *Natura non facit saltum* (Nature does not proceed by leaps). This old Latin aphorism is so common and canonical that its origins have been lost in a forest of multiple claims and attributions. Philosophers often cite Leibniz, but biologists know (and the latest edition of Bartlett's *Familiar Quotations* gives us the nod) that Linnaeus codified and popularized the phrase by making it the watchword of his *Philosophia Botanica* of 1750.

We also know that Darwin continually invoked *Natura non facit saltum* as the fundamental epitome for his broadest view of nature. He cites the phrase seven times in the first edition of the *Origin of Species*, once as a chapter heading, and described on all other occasions with the well-chosen "canon"—as, for example, "that old canon in natural history." In several passages, Darwin explicitly identifies his theory of natural selection as the architect of such gradualism in nature:

> As natural selection acts solely by accumulating slight, successive, favorable variations, it can produce no great or sudden modification; it can act only by very short and slow steps. Hence the canon of "Natura non facit saltum," which every fresh addition to our knowledge tends to make more strictly correct, is on this theory simply intelligible.

But this phrase, and the image thus evoked of imperceptible gradualism as nature's mode of change, did not command universal assent. Thomas Henry Huxley may have been Darwin's "bulldog," but he also made his disagreement clear, expressing his major reservation in a famous letter to Darwin written just after his first reading of the *Origin:* "You load yourself with an unnecessary difficulty in adopting Natura non facit saltum so unreservedly."

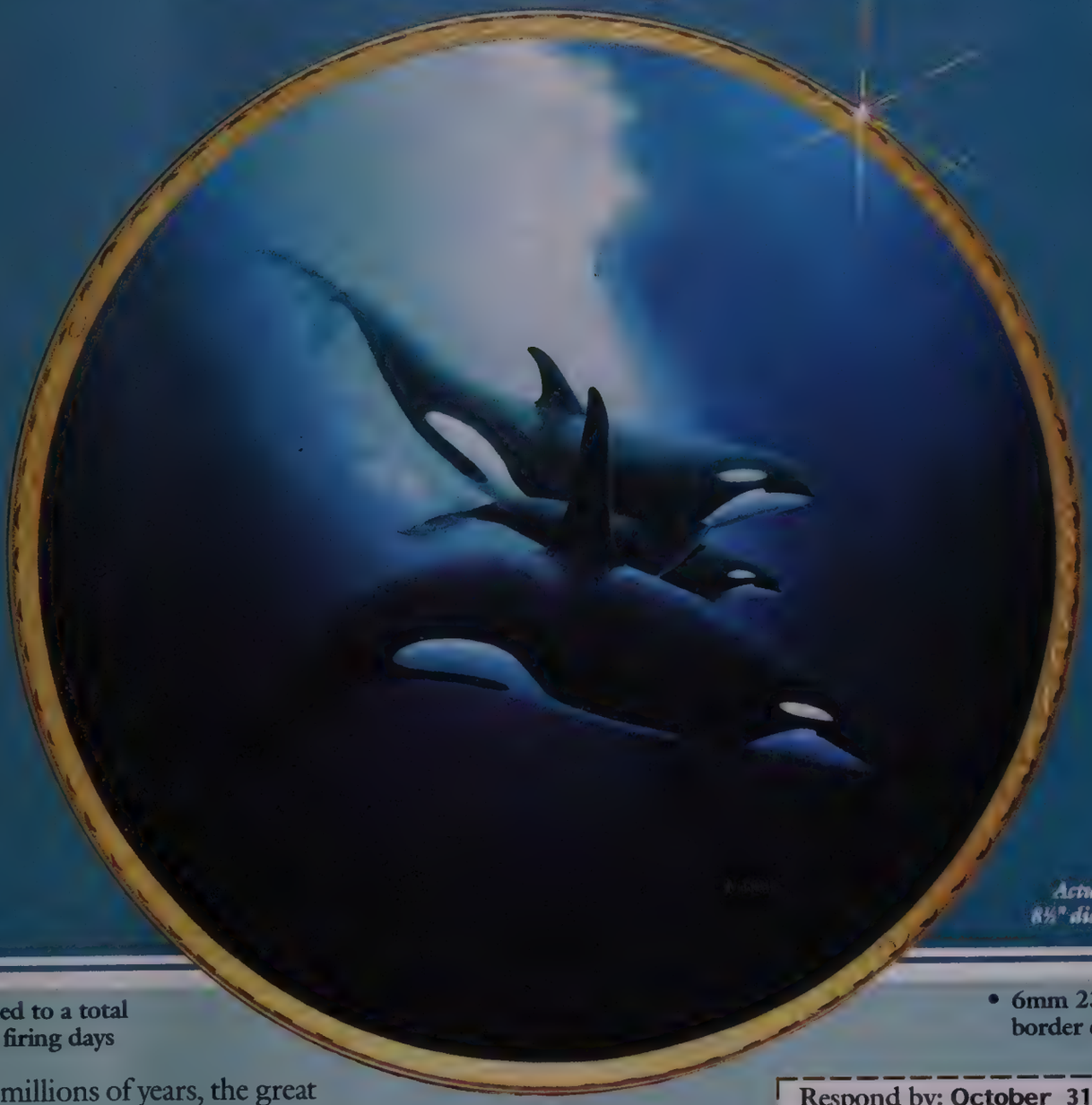
As illustrated by its focal status in fields as diverse as economics and evolutionary biology, *Natura non facit saltum* embodies a major issue in science, and in all intellectual life—for what could be more basic or important than *the* nature of change. And as demonstrated by Huxley's demurral, the aphorism popularized by Linnaeus and embraced as fundamental by Darwin and Marshall represents no self-evident truth, but a testable claim that might more often be wrong than right.

In any case, this key question of the pace and mode of change carries implications that transcend any scientific resolution, for practical questions of culture and politics must inevitably be engaged. In particular, a claim for the necessarily gradual nature of change offers firm support against the specter of revolution—both t
conservatives who wish to maintain an e
tablished order and to mild reformists wh
advocate change at a balanced, measure
and imperceptible pace, with minimal di
ruption of social stability. A successfu
equation of gradualism with nature's i
evitable way becomes a powerful politic
tool, whether explicitly so intended or no
Science and general culture must alway
be intertwined, but the links are especiall
clear for issues of such joint conceptu
importance and social implication.

Consider two examples: one rather di
tant from immediate American concer
(and therefore tending to strike us
merely amusing); the other much clos
and consequently more painful. On
might guess the man's social status an
implied politics from his name (and on
would be right in this case); so conside
the brief against revolutionary chang
penned by the British anthropologist Au
gustus Henry Lane-Fox Pitt Rivers whe
he established a museum of the history
human technology in 1891. (Note also h
specific invocation of *Natura non fac
saltum* in English translation.)

> For good or evil...we have thought prope
> to place power in the hands of the masse
> The masses are ignorant, and knowledge
> swamped by ignorance.... The knowledg
> they lack is the knowledge of history. Th
> lays them open to the designs of dema
> gogues and agitators who strive to mak
> them break with the past, and seek the reme
> dies for existing evils, or the means of futur
> progress, in drastic changes that have no
> the sanction of experience. It is by a know
> edge of history only that such experienc
> can be supplied.... The law that Natur
> makes no jumps, can be taught by the hi

Great Mammals of the Sea



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...echanical contrivances, in such a ... at least to make men cautious how they listen to scatterbrained revolutionary suggestions.

If you ever wondered why Booker T. Washington was so lauded by white Americans as an apostle of "Negro progress" in his day, but seems such an ambiguous figure to most African Americans today, consider his 1904 statement on the necessarily gradual character of racial equalization:

> For my race, one of its dangers is that it may grow impatient and feel that it can get upon its feet by artificial and superficial efforts rather than by the slower but surer process which means one step at a time through all the constructive grades of industrial, mental, moral, and social development which all races had to follow that have become independent and strong.

I bring up this broad issue for a more personal reason based on a conjunction of two events: a trip to Russia in July 1992, which (among so many other complicated thoughts and feelings) powerfully evoked an interesting piece that I had read in the *Boston Globe* for May 3, 1992, by the syndicated economic columnist David Warsh. This article carried an odd title for a self-professed capitalist: "Redeeming Karl Marx."

Warsh bases his argument on a pungent irony now being played out in Russia. On the one hand, and for all the world to see, Marx's economics has failed spectacularly, at least in the largest and longest experiment ever carried out in its name. (One might, of course, keep the faith and label the experiment a perversion, but only the most religiously committed could fail to extract some powerfully negative evidence from the Soviet collapse.) Warsh writes, with measured voice and generosity toward the vanquished:

> Does that mean that Marx will be consigned to the intellectual scrap heap? Probably not. As a symbol, he'll be around as long as people hunger for justice—a tarnished but evocative figure, in whose name great crimes have been committed, not unlik... other great religious figures, Jesus and Mo... hammed.

But Warsh then argues that as Marx'... economics has failed, he is being re... deemed by the success of his broader, un... derlying philosophy—in particular, hi... commitment to the non-gradual, punctu... ated character of change in complex sys... tems. Warsh continues from the previou... quotation: "Within social science, how... ever, he's likely to be remembered for th... introduction of the theory of punctuate... equilibria."

Warsh then uses the rest of his colum... to argue that the gradualist theory of gen... eral change, so important to Darwin an... others, is being challenged in field afte... field by an alternative model positing sta... bility as the normal (and actively persis... tent) state of complex systems, wit... change as a rare and relatively rapid dis... combobulation that moves the syster... from one durable position to another... Warsh gives three diverse examples... spread throughout our century and indi... cating the broad nature of this punctua... tional challenge to gradualism (he migh... have supplied many more, including ca... tastrophe and chaos theories in mathemat... ics, and Foucault's notions of social an... intellectual change): introduction of th... quantum in early twentieth century phys... ics; Thomas Kuhn's punctuational theor... of the history of ideas in science, with hi... distinction between long periods of "nor... mal science" and short episodes of revolu... tionary change (see *The Structure of Sci... entific Revolutions,* 1962); and the theor... of punctuated equilibrium in evolutionar... biology, proposed by Niles Eldredge an... myself in 1972.

Eldredge and I argue that most specie... are stable for most of their geological life... times, often lasting many millions o... years—the equilibrium—and that chang... does not usually occur by imperceptibl... gradual alteration of entire species bu... rather by isolation of small population... and their geologically instantaneous trans... formation to new species—the punctua... tion. Our theory entails no new or violen... mechanism, but only represents the prope... scaling of ordinary events into the vast... ness of geological time. An isolated popu... lation may take a thousand years to speci... ate, and its transformation would therefor... appear glacially slow if measured by th... irrelevant scale of our personal lives. But... thousand years, appropriately recorded i... geological time, is only an unresolvabl...

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usually preserved on a single plane, in the lifetime of species not often live for several million years in stasis. (In any case, our theory of punctuated equilibrium is only one example of a much broader intellectual movement, with many antecedents. It was kind of Warsh to borrow our name for the general phenomenon, but we cannot lay any claim to priority or originality for the overall scheme, only for a particular application.)

Warsh certainly recognizes that this theme invokes one of the "big" issues in intellectual life:

> More largely, the punctuated equilibrium debate is really an argument about the fundamental nature of change. Is it "easy," or is it "hard"?... In each case, punctuated equilibrium seemed to strike at one of the very deepest foundations at [*sic*] our knowledge of the world, namely the conviction that change would always be a matter of smooth little increments at the margin of things.

Warsh then argues that Marx's theory of economics and revolutionary historical change represents the most important expression of punctuational thinking in the social sciences. He also notes how conventional economic gradualists understood the challenge and responded:

> Marx's opponents recognized immediately the challenge that his views posed to their science—not only in the streets, but at the deepest intellectual levels. The marginalists—Jevons, Menger, Walras—answered almost immediately with the easily mathematized concept of marginal utility and equilibrium analysis, in which all elements are kept in place by mutual counterpoise and interaction, that informs our view of economics down to the present day. [Warsh then recounts the tale of Marshall and *Natura non facit saltum* and continues.] From his Cambridge pulpit, Marshall's star pupil, John Maynard Keynes, also preached against the very concept of revolution, citing the same pieties about the impossibility of discontinuous change that had comforted Darwin 75 years before.

This argument brings Warsh to the climax of his ironic theme: just as Russia displays the abject failure of the largest experiment in Marx's particular economic theory, the growth of punctuational thinking validates his broader views on the nature of change.

> Economics scholars are only now bringing discontinuities into a central place in their field, mainly through the study of increasing returns to scale. Economics is finally moving slowly toward becoming a history of technology and institutions, as Marx had wanted. But you don't need even a smattering of recondite economics to understand Marx's enduring place in the modern world. His memorial is the word revolution, meaning not so much the bullet in the eye of an Eisenstein movie, as the relatively sudden development, generally unanticipated but quick to spread until people "accept the ne as unthinkingly as they once opposed it," Cyril Stanley Smith once put it.

Obviously, I applaud and greatly appr ciate Warsh's argument and his identific tion of the new Marxian irony. But missed the most ironic point of all—pro ably because you have to be "on site" Russia today to see it for yourself. Yes, t Russian reality does discredit a speci Marxist economics, but Warsh didn't re ognize that the same reality also illu trates, in a most eerie and striking manne the second component of Marx's thes the validity of the larger model of punct ational change. As I look back on my r cent week in Moscow and Saint Peter burg and try to epitomize this remarkab and unprecedented experience in my tra els, I can only offer the following expre sion: all the tension, all the strangeness, a the confusion can be integrated by reco nizing that Russia now resides within th rarest of historical moments. Russia presently in the midst of a punctuation th must soon resolve itself in one way or a other—into some form of promise or pro perity, or some species of chaos and diss lution. The Russian people, betrayed b one side of an ideology, are now displa ing the valid generality of a deeper theo of change.

As a former philatelist, I can experienc punctuational chaos vicariously in th pages of my stamp album by tracing th hyperinflations of Hungary in 1946 an Germany in 1923. My first German seri for the year, showing a bird on the win begins with 5 Pfennigs and ends with 20 Marks (a Pfennig is ⅟₁₀₀ of a Mark). Th next starts with a crew of workmen at Marks and ends with just numbers 75,000. The next begins at 5,000 Mark (overprinted on an old 40-Pfennig stamp and runs to 2 million (overprinted on a old 5,000-Mark stamp). Subsequent issue show numbers only, for there is no room for any picture. My last sequence begins 500,000 Marks and ends with a stamp fo 50 billion (yes, 50,000,000,000—and s written out along the bottom edge). Good bye overnight to a lifetime of saving Workers were paid daily and then wen forth to buy anything they could find—fo the money would be worthless tomorrow

The Russian ruble has not hyperinflate to this extent, but the decrease in compa ative value to the dollar is more than hundredfold. In 1970, I rode the world greatest system of public transportatio the Moscow subway, for just 5 kopeck

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...ents by the official rate of ex-...e—one ruble for one dollar). The ...ce has just risen twenty times to one ...ble, but the exchange rate now stands at about 130 rubles to the dollar—and I now rode the subways, still functioning and still the world's best, for less than one cent (an odd feeling for an old New York kid who remembers the nickel ride of his youth).

Kopeck coins are effectively worthless and have largely passed from use, although you need to save your old 2 kopeck coins to make a (now virtually free) public telephone work. Shoppers must walk around with wads of bills to fit the old cliché "thick enough to choke a horse," for not enough new bills of higher denomination have been printed, and you need enormous stacks of the old one-, three-, and five-ruble notes to buy much of anything in this purely cash economy.

I had never realized the full extent of hardships and confusions caused by inflation of this order. I was told over and over again that most prices have risen thirty to fifty times, while salaries rarely increase more than tenfold (that is, when your employer can find enough rubles to pay you). Combine this wage and price disparity with the fall of the ruble relative to Western currencies, and you can sense the dual frustration. Just two stories, among scores that we heard and witnessed, as a testimony to the annoyances, tensions, and Catch-22s that arise in such a situation. I journeyed to Russia as part of an American delegation of four evolutionary biologists sent by our National Academy of Sciences to assess prospects for cooperation with our Russian counterparts. W visited the wonderful paleontological mu seum in Moscow, built on the city's ou skirts just a few years ago, and one of th world's best both in content and displa But the museum is now closed indefinitel for two major reasons. First, they have le all their best fossils to Japan, where the will be displayed and televised for a fee o $100,000—a resistible temptation, pe haps, in the past, but we are now speakin of more than 10 million rubles, otherwis unobtainable. Second, they used to pa their support staff from the small admis sion fees that all could manage. Now the cannot charge enough "at the gate" to af ford the salaries that would keep the mu seum open. (I am reminded of America amateur musical groups that must los money every time they perform, even they sell out the house—and can therefor only break even by not performing at all!

For a second tale, consider the irony o altered troubles. In the bad old days, scie tists could rarely travel abroad because po litical repression and bureaucratic ineff ciency conspired to make visas and othe necessary paperwork almost unobtain able, even when you had money for ticket and expenses. Now you are perfectly fre to go, but inflation has placed tickets ab solutely beyond reach (for internationa fares are geared to Western prices). Labo ratory directors who once made the equiv alent of several hundred dollars a mont now earn between thirty and forty dol lars—and even the hour's hop from Sain Petersburg to Helsinki represents severa months' earnings, while America can onl be measured in years.

Of course, all these inflationary tale only make sense when items are availabl that you wish to purchase. In some re spects, Moscow has become an orgy o selling as individuals are now free to en gage in commerce, and most land is un owned and therefore available for you shack, your stall, your table, or just yo standing and silently holding the item o two that you wish to flog. Political free dom has spawned a predictable outpour ing of once-banned items. I appreciate the symbolism (at least) of religious calen dars and charts of the Romanov dynasty o czars. But I must confess to feeling som dubiety as I purchased an astrologica chart for 1992, a pamphlet entitled *Num bers of the Kabbala,* and a soft-porn pape named *Venera,* featuring articles on teen age sexuality, Don Juan, and syphilis (Other items, once favored, have foun new uses. Real toilet paper, for example, i

"Let's all join in saying 'hallelujah' for the news that the science community has scrapped the big-bang theory of the creation."

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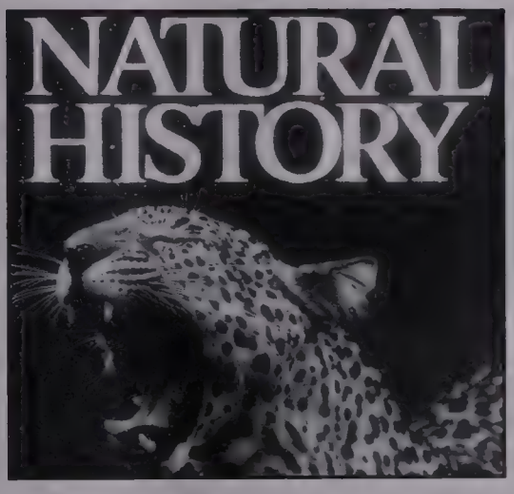

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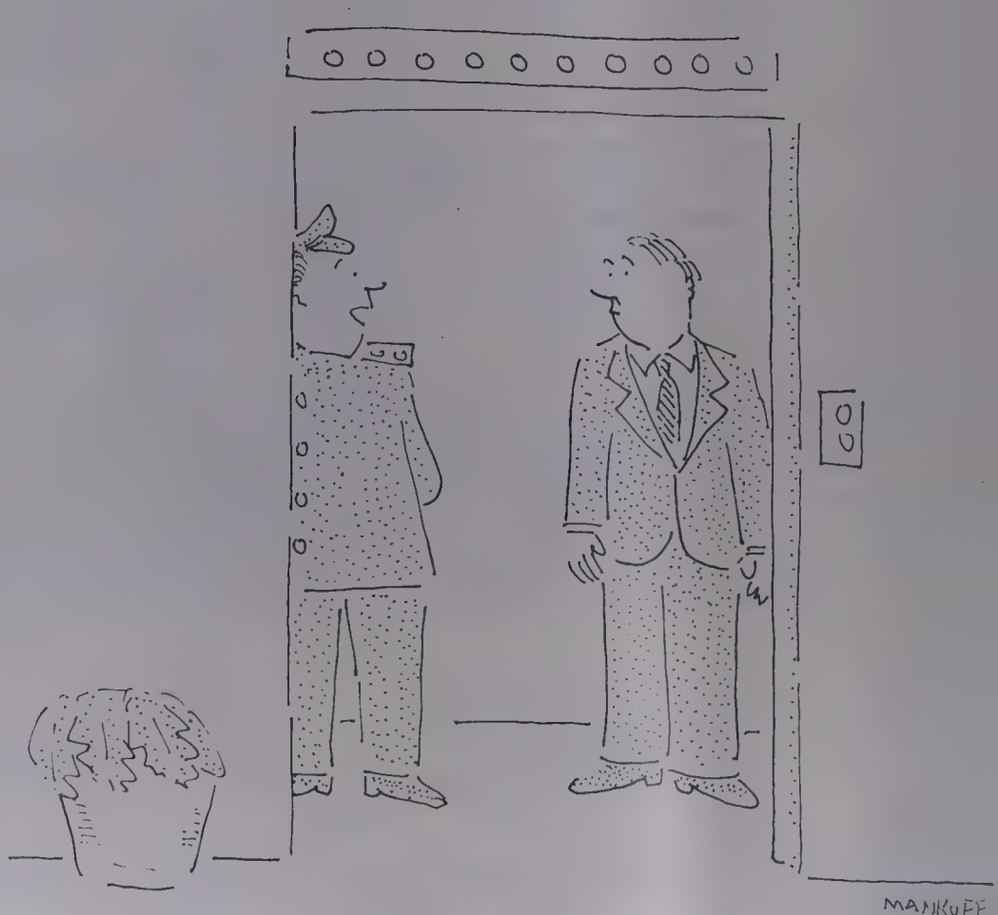
hard to come by. The stalls at the Vavilov Institute of Genetics, named for Russia's primary martyr to Lysenkoism, the great agronomist who died in Saratov prison in 1943, provide old pamphlets, ripped up, as substitutes. I deciphered two interesting sources: election forms for the Supreme Soviet of the USSR and a learned treatise entitled *Leninism and Problems of World Development.*)

Anything available is sold. Stalls labeled "flowers" hawk vodka; others advertising "ice cream" offer cigarettes. One farmer plunked down thirty crates of cabbages outside the October Square subway station. On Tverskaya Street, Moscow's main drag (the old name from czarist days, now reclaimed and replacing the Soviet rechristening as Gorky Street), an old lady sells eggs, one by one. Nearby, an entrepreneurial young man hawks his disparate stock of individually wrapped sticks of chewing gum, cans of Pepsi, and dried fishes—with each fish neatly propped up between two soda cans.

But many items, much desired, are simply not available. Basic foods are easily obtainable, but choice is nearly absent. Bread is plentiful (and good as ever), but meat and cheese stores feature thirty empty shelves and one counter with one selection (and no long lines or sense of panic, so I assume that only variety, rather than substance, is lacking). I stayed at a colleague's apartment in Saint Petersburg. As a superb cook, she lamented: "Before I used to decide what I wanted to make and then go out and buy the ingredients. Now I buy what I find and then decide what I *can* make."

Odd patterns of fluctuating availability illustrate the chief dilemma of an economy in disarray, with selling almost feverish and orgiastic, but production stalled—for it takes no particular genius to realize that, ultimately, you cannot sell if you do not make. Consider a typical touristical example (and therefore merely funny rather than tragic, for only visitors are deprived of nonessentials): You cannot buy either postcards or booklets of the Hermitage, the great art museum of Saint Petersburg, and even more magnificent than my already exaggerated imagination had anticipated. (Or rather, you can find one or two postcards of the most unpopular items—the French rococo *Triumph of Venus,* by Boucher, for example, but nothing by Leonardo or Rembrandt. Hawkers push pamphlets of the outlying palaces—



"Globally warm enough for you?"

Pushkin, Pavlovsk, and Petrodvorets—hoping that visitors, unable to read the Cyrillic titles, will mistake them for the Hermitage.) Since tourists carry precious dollars (not only rubles), you can be sure that postcards of the Hermitage would be available in abundance (as they formerly were) if anyone could manufacture them. Either there is no paper, no ink, no plates, or no working presses.

More seriously (since we now speak of items that local people need), highly important (if not absolutely essential) nonfoodstuffs cannot be found in stores—no thread, no glue. So what is to be done? Human ingenuity now takes over. No thread is being manufactured, but there is thread in Russia—an unused spool or two in most houses. So word gets around and people with a little disposable thread go down to the impromptu market area with the colorful and highly descriptive name of *tolchok*—literally a "jostling place"—where thousands aggregate in tight knots of humanity (this is not a flea market in any Western sense) and hold up the items they wish to sell. So you make a few rubles for your thread and then find the corner of the *tolchok* where other folks are selling the glue. The *tolchok* is pure tension, not rustic charm.

A week's visit by four evolutionary biologists cannot begin to sort out the reasons for this economic punctuation, this historical moment of dangerous instability. I got an eerie sense of incompleteness from my inquiries. Just as, suddenly, all former Nazis disappeared into thin air from Germany after World War II, you cannot find an admitted former Communist in Russia. My respondents, with some oversimplification short of caricature, basically fell into two groups: Yeltsin people, who admit to current chaos and hardship but say that Russian ingenuity, combined with new economic freedom, will find an exit into capitalist prosperity; and Gorbachev people, who celebrate the new political freedom but state that a tragic mistake was made in dismantling the economy. The old system, they argue, however corrupt and inefficient, worked after a fashion. It needed massive reform, even complete restructuring along entrepreneurial lines, but it should not have been torn down before new modes had been established to assure continuity in production. Now, too, much farming and manufacturing has simply ground to a halt. The tire factories used to make products, and trucks or trains somehow got the tires to the body factories where Ladas and Volgas (unlovely but functional) were put together. Now little is made, and what is made often cannot be transported. On the train from Moscow to Saint Petersburg (eight hours with no food or drink), we passed by one agricultural town after another, with fields lying fallow.

It is almost a bitter joke. Marx lives in Russia not as an economist—where their version of his system failed so abysmally, and of its own weight—but as a philosopher of change, where his insightful and accurate view of transitional stages captures the heart of their dilemma and danger: their current (and necessarily transitory) existence in the midst of a punctuation that must soon lead to some stable form of destruction or salvation. But you cannot think much about the nature of future stabilities when you must struggle to keep daily food on the table. Immediate survival is best buoyed by a good sense of humor in the face of this bitter joke—and no one can beat the Russians in this category. The currently favored version of Russian nesting dolls, available at all souvenir stands, features a big Yeltsin on the outside and smaller dolls within—first Gorbachev, then Brezhnev, Khrushchev, Stalin, and finally, a tiny Lenin at the core.

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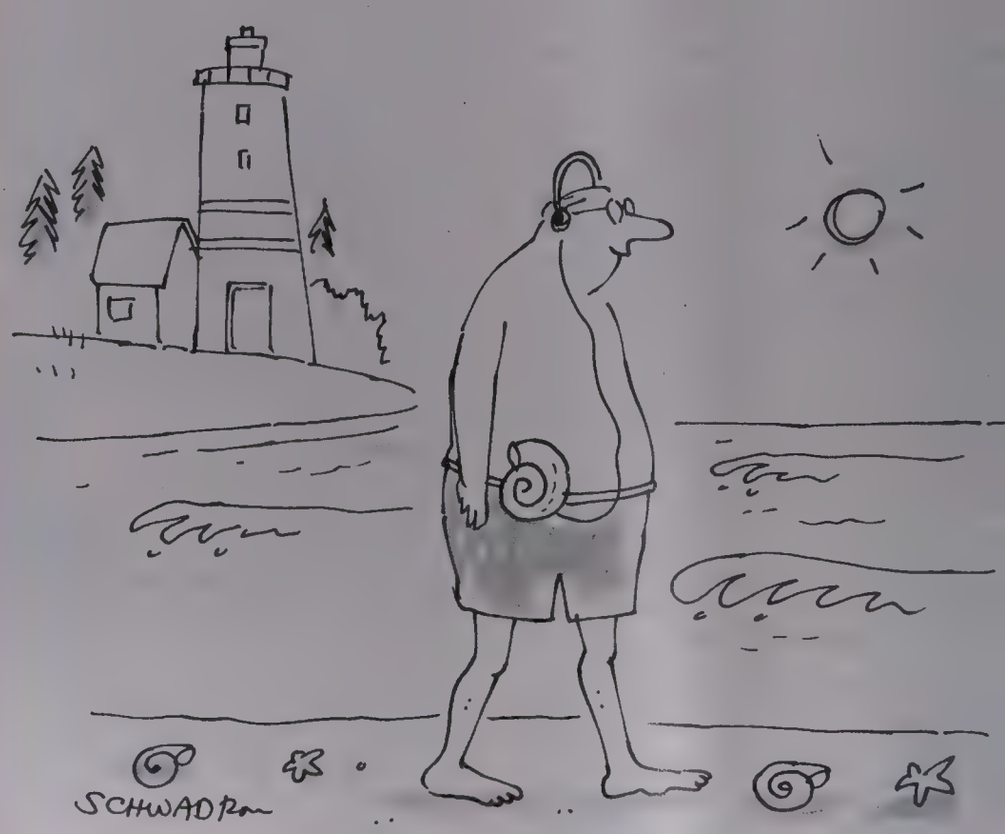
But one crucial difference between Marxian and modern views of punctuational change may well delineate both Russia's dangers and hopes. Marx lived and worked in the heyday of mechanistic science, the height of general conviction among intellectuals that the natural world, and the social as well, worked in a predictable and lawlike manner and could be explicated with rigorous methods that had been so successful in the physical sciences. Marx himself had a much more subtle view than most of his contemporaries of the differences between human and natural history. He understood that the evolution of consciousness, and the consequent development of social and economic organization, introduced elements of difference and volition that we usually label as "free will." Marx penned a wonderful aphorism on the balance of freedom and necessity at the beginning of his pamphlet *The Eighteenth Brumaire of Louis Bonaparte:* "Men make their own history, but they do not make it just as they please." (The degree of social determinism in Marx, and the nature of differences between him and Engels, is a classic and contentious issue in Marxist scholarship. I cannot even begin to treat this subject here and will only state my own "compromise" feeling that whereas Marx may have been more aware than Engels of the difference between natural and social, and the lesse determinism implied by social and eco nomic causation, he was still a child of hi mechanistic age and fundamentally com mitted to the search for predictive laws o historical development. I regard S. H Rigby's recent book *Engels and the For mation of Marxism* as the best source o this subject.)

But Marx's punctuational view of his tory embodied a related conviction that di rections of change are progressive, pre dictable, and well-nigh inevitable. Hi closest friend and colleague, Friedrich En gels, took a hard line in advocating a "iron necessity" that evolution mus progress to consciousness: "It is in the na ture of matter to advance to the evolutio of thinking beings" (quoted from *The Di alectics of Nature*). But Marx also advo cated a predictive view of evolution an criticized Darwinian natural selection fo not upholding the inevitability of progres In an 1866 letter to Engels, Marx praised now-forgotten work of P. Trémaux as " very significant advance over Darwin" be cause Trémaux supposedly established rationale for necessary progress: "Prog ress, which Darwin regards as purely acci dental, is essential here on the basis of th stages of the earth's development."



Marx knew that social and economic evelopment did not simply ape evolu- onary change, but he certainly hoped for predictive theory of history, with pro- ressive stages proceeding in a punctua- onal manner from primitive communism o slavery to feudalism to capitalism and nally to true communism. And he stated n *Capital* that his "own dialectical ethod" proved the forthcoming revolu- onary transition from capitalism to so- ialism—"the necessity of the present rder of things and the necessity of an- ther order into which the first must in- vitably pass over."

Thus, a Marxian style of punctuational hange would lead us to view the current ussian crisis as a break between stages nd a foreshadow of the next inevitable so- ial order. At least we would have the omfort of predictability (with, perhaps, ne sadness of not liking the next neces- ary stage). But modern punctuational- sm—especially in its application to the agaries of human history—emphasizes he concept of contingency: the unpre- ictability of the nature of future stability, nd the power of contemporary events and ersonalities to shape and direct the actual ath taken among myriad possibilities. ontingency may provoke more anxiety n its failure to specify an outcome, but it urely embodies more hope in the power ranted to people over their own futures. Ve are not pawns in a grand chess game layed by inexorable natural (and social) aws, but effective rooks, knights, bishops, ings, and queens on a revolving board of lterable history with no set outcome.

Let us give a last word about modern ussia to an older Russian who thought eeply about history. Tolstoy discussed his iews on cause and indeterminacy in his- ory in two long epilogues to *War and eace*. In Chapter 2 of the first epilogue, e captured the essence of contingency in lovely dialogue:

Why did it happen in this and not some ther way? Because it happened so! Chance created the situation; genius uti- ized it," says history. But what is chance? what is genius?

I think that I understand something of hance. Genius I cannot fathom, but I now that it exists in abundance in Russia nd elsewhere. Perhaps we will punctuate o a better place.

Stephen Jay Gould teaches biology, geol- gy, and the history of science at Harvard University.

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Columbus and the River of Birds

The great navigator's route intersected that of other long-distance travelers

by Edwin O. Willis

Five hundred years ago, and thirty-one days out on the Atlantic, the sailors of three small ships must have wondered if they would end up in the Indies or at the end of the earth. Near mutiny and false sightings of land had left them divided on what tack to take. Abruptly, on October 7, 1492, they sailed into a virtual river of migrating birds, which continued south throughout the night. None alighted on the ocean, and some that came down on the ships were land rather than marine birds. Reassured, Columbus angled southwest on October 8 to follow the avian river and, four days later, discovered the New World.

Had Columbus sailed from the Canary Islands two months earlier or just days later than September 6, he may well have missed this avian phenomenon. We now know that the river of shorebirds, traversing more than 2,500 miles of ocean between eastern Canada and South America, flows only from August to mid-October. Taking into account the change in the calendar within the last 500 years, which places Columbus in the West Indies more than a week later than the dates usually cited, his fortunes were even more remarkable, for he must have caught one of the last waves of migrants for the year. If the men on Columbus's caravels had not sighted the birds, they might have continued west toward Florida or they might

Once-abundant shorebirds, Eskimo curlews are now almost extinct.
Oil painting by Robert Verity Clem; Library, The Academy of Natural Sciences of Philadelphia

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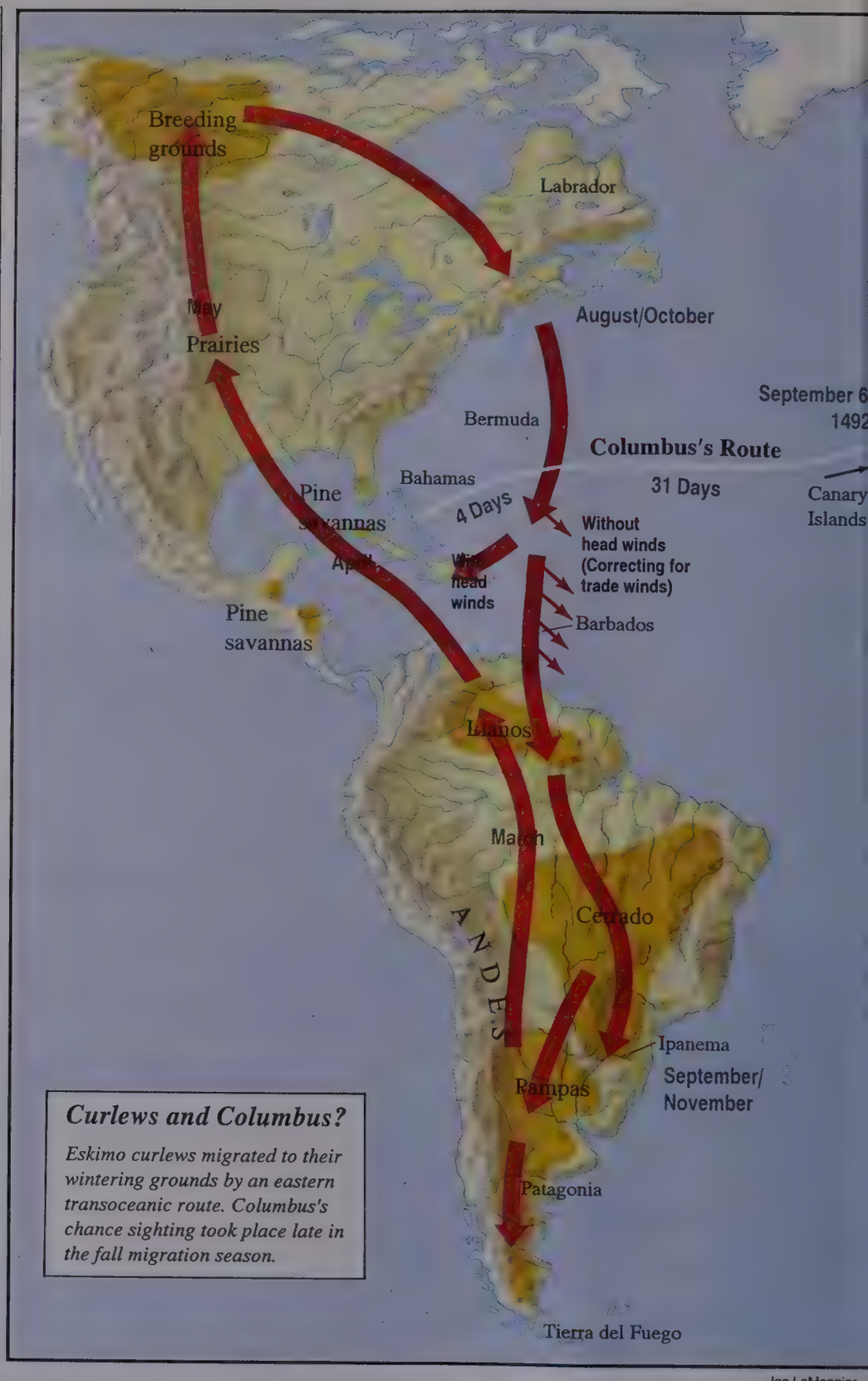

Curlews and Columbus?

Eskimo curlews migrated to their wintering grounds by an eastern transoceanic route. Columbus's chance sighting took place late in the fall migration season.

Joe LeMonnier

well have turned back; even Columbus underestimated the distance to the Indies.

Today, the bird river that Columbus intercepted at the very end of the migration season includes shorebirds, notably thousands of white-rumped sandpipers and American golden plovers, and may include songbirds, such as blackpoll warblers. While the migrating river has thinned over time, the phenomenon has attracted much recent interest, from radar studies of migration in progress to physiological calculations of the fat and water needed to fly the distance and conservation attempts to protect the food-rich stopover sites where the birds pause to refuel for the transoceanic flight. We cannot be certain which shorebird was most common in 1492, but one species abundant then and absent today is the Eskimo curlew.

Curlews are large sandpipers with downcurved bills, nesting in the Arctic or northern prairies and wintering to the south, at times crossing thousands of miles of ocean en route to South America, the Pacific islands, or Australia. The downcurved bill allows the tall birds to rapidly

pick up prey in mud or short vegetation without crooking the head so much that they would be unaware of the approach of predators such as falcons. Ibises, which are larger and which dominate curlews in many southern regions, have similar bills.

The Eskimo curlew is small in comparison to its North American relatives, the long-billed curlew and the whimbrel. Its closest relative is the little curlew of Asia, which winters in Australia. The last recorded specimen of Eskimo curlew was shot on Barbados in 1963, but there have been a few sightings or photographic records in every decade of this century.

During their fall migration over the north Atlantic, Eskimo curlews tended to be so fat that nineteenth-century North American hunters, who called them doughbirds, claimed that their breasts split on impact with the ground when they were shot down. The birds were reputed to double their half-pound weight at staging areas before undertaking long flights on their migration. The very strategy that made the birds fit for a marathon flight—putting on fat at the onset—also made them attractive market and game birds, and they were slaughtered wholesale. Similar increases in weight are registered in some of their smaller sandpiper relatives today, leaving the birds almost too fat to fly. While most individuals do not reach this level (equivalent to a 150-pound man gaining his weight once over in less than a month), many increase in weight by half several times each year. Feeding gluttonously at stopover sites, they use the fat as fuel on long migratory flights over oceans, tropical forests, and other areas where shorebird fare is scarce. The record for flight time and economy of fuel is held by a banded semipalmated sandpiper, which with only 23 percent fat (eight grams) flew from Maine to Guyana in two days, perhaps helped by tail winds.

Eskimo curlews nested inland, on the short-grass tundra of Arctic Canada and Alaska. In August, they began their odyssey by flying to the rocky plains of Labrador and the Saint Lawrence River region of eastern Canada. The lure of these "barrens" lay in millions of low crowberry bushes. At summer's end, Eskimo curlews rested and sometimes fed on the nearby beaches or headlands but spent the most productive time inland, gorging on crowberries until their bulging bellies were stained purple. Also known as curlewberries, the fruits sustained hundreds of thousands of the birds. Crows and foxes also took advantage of the crowberry crop, and

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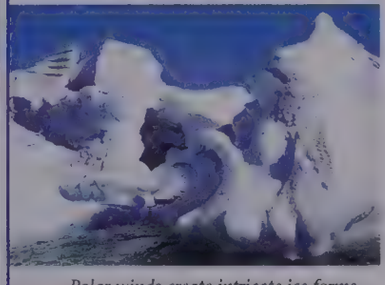

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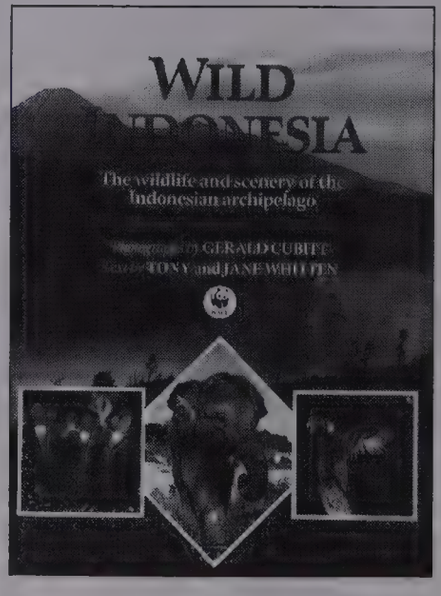

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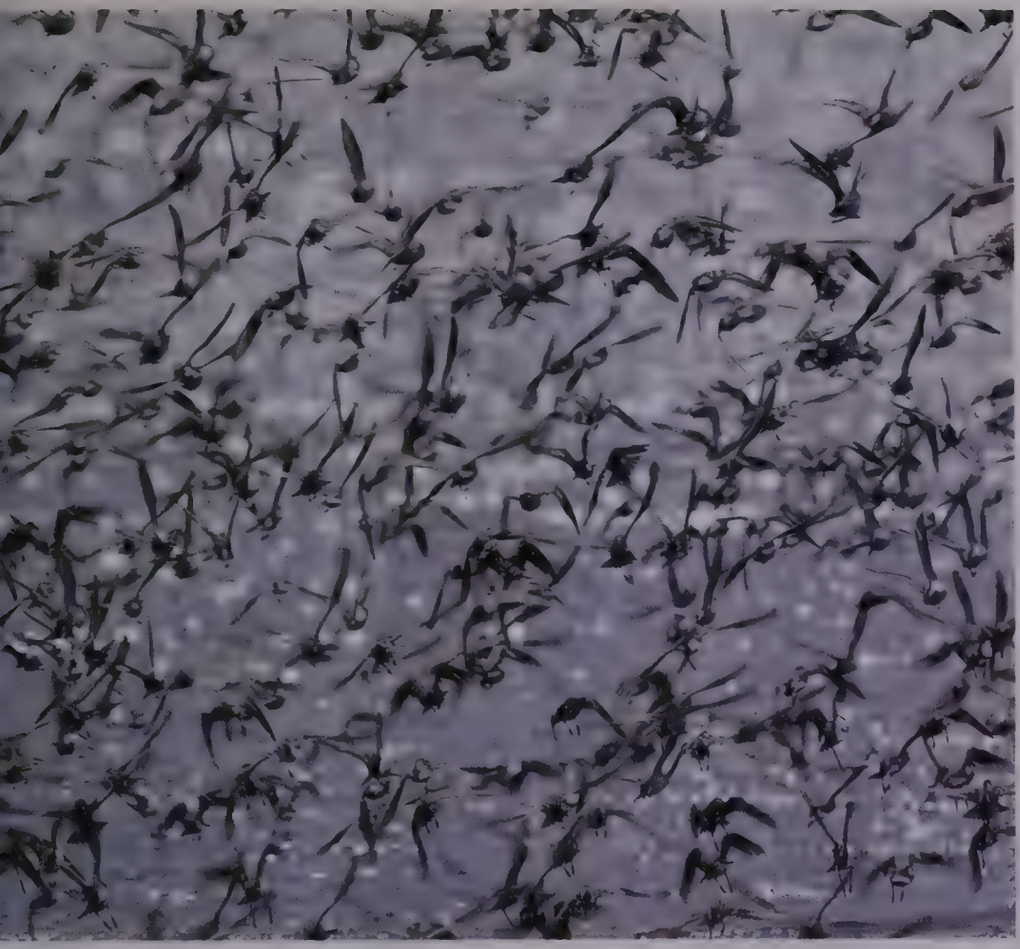
foxes relished the occasional succulent curlew as well.

From late August to early October, flocks of fat curlews, stimulated by cold northwest winds, swirled over the barren grounds and headed out to sea over eastern Canada. Adults migrated first and young birds left later. Only with eastern gales were they forced ashore at Cape Cod. The fat they had put on during the previous month gave the birds enough fuel and water to fly nonstop over 2,500 miles of hostile ocean, but not if they had to fight head winds. On days when warm winds blew from the south, the curlews and other migrants rested. Presumably, a day or so before Columbus sighted the birds, cold north Canadian winds had borne these late migrants in his direction; otherwise the avian river would never have materialized in his path.

The precise route of the migrating curlews depended on winds encountered during the journey. On September 13, 1851, well east of Bermuda, schooner captain Edwin Jones reported multitudes of birds going south for two days and a night, until, checked by a south gale, they dropped in on Barbados, where many were killed. Fortuitously, Columbus had seen his birds heading southwest toward the Bahamas or Antilles, perhaps because of strong south or southeast winds. Had he not passed on a day of head winds, he probably would have seen birds correcting for the normal east breeze by flying southeast, and had he followed them, he would have had a long trip to Surinam.

We do not know for certain where the curlews normally made landfall. They probably would not have descended on the shores of Venezuela or the Guianas, as do several other species of sandpipers, for they would have found many competitors and little food on mud flats and sandy beaches. The curlews, and the American golden plovers that probably accompanied them, liked low-grass plains, such as those of the llanos and savannas from interior Colombia eastward. The now hungry curlews may have made one last, supreme effort, flying over the eastern Andes or over coastal forests. In October, at the end of the wet season, the interior plains are full of grasshoppers and other nourishing insects.

After refueling on the savannas, Eskimo curlews probably flew another thousand miles or two across Amazon forests to the llanolike belt of savanna to the south. Unlike the llanos, this open scrubland, or *cerrado,* of central Brazil and



After breeding in northern Canada, semipalmated sandpipers fly to the Atlantic coast and then over the western Atlantic to Venezuela and beyond.
Frans Lanting; Minden Pictures

eastern Bolivia would be just sprouting during the austral spring rains of September and October and giving rise to the huge flights of winged termites that emerge here when the wet season returns. Written accounts are few, but we know that in the early 1800s, Austrian naturalist Johann Natterer collected several Eskimo curlews between September and November near the iron mines of Ipanema at the south end of the *cerrado*. Some curlews may have simply flown on to the pampas of Argentina, without descending on the bushy or weedy *cerrado*; others, however, may have made pit stops along the way at the many burned zones and open lagoon areas that promised insects.

Such early naturalists as W. H. Hudson (author of *Long Ago and Far Away* and *Green Mansions*) reported curlews feeding on the Argentine pampas, from which many flew on to a final destination on the steppes of Patagonia and Tierra del Fuego, the southern counterpart of the treeless tundras where they began their lives.

On the return trip during the following southern autumn, they took a different route, which Columbus could have crossed only on his second and later voyages. They flew north, with possible stops

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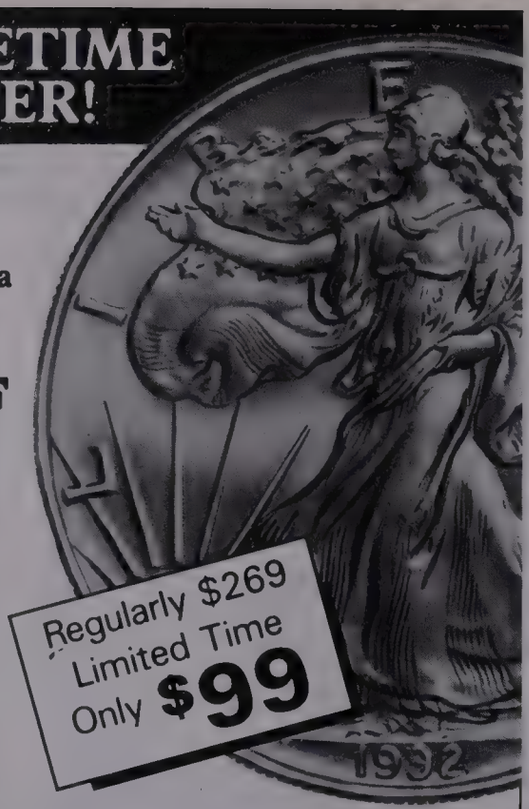

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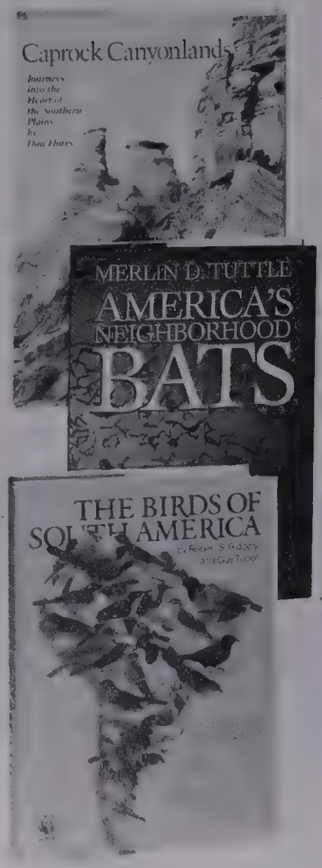

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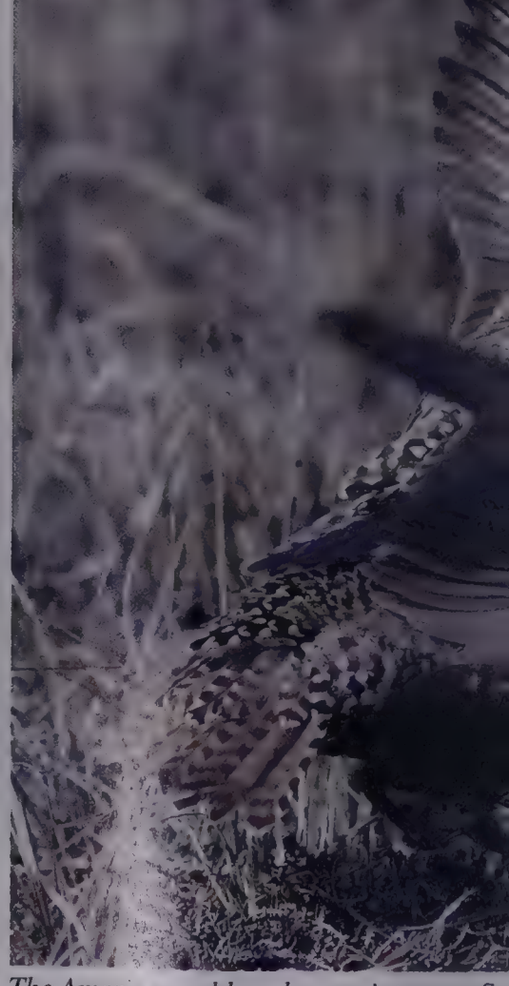
on the *cerrado* and llanos. The former would have been full of late-summer insects; the latter characterized by burned zones, new spring rains, and termites. In late April and May, the curlews arriving across the Gulf of Mexico descended on the prairies from Texas north, where they fed before undertaking the next leg of the flight in May and June to their nesting grounds on the tundra.

Along the route, nineteenth-century market hunters slaughtered the birds by the thousands. This gauntlet, along with the ones the birds were forced to run during the fall in eastern North America, on the pampas near Buenos Aires, and elsewhere along the way, drastically reduced their numbers. Once its numbers dropped, the species was unable to recover, even after market hunting ceased. Perhaps genetic problems caused by a population bottleneck overwhelmed the curlews, or perhaps the now fire-free or grazed pampas, *cerrados,* llanos, and prairies no longer supplied their vital food needs. If just one stopover area vanishes, a species can vanish as well.

We now know that Columbus was mistaken when he assumed that the river of "field" birds indicated that land was



The American golden plover winters on South American grasslands.
Wayne Lankinen, Bruce Coleman, Inc.

nearby. Most, if not all, of these birds were in the middle of transoceanic flights of thousands of miles. How did this unlikely phenomenon begin? Perhaps a few lost but fat individuals occasionally managed to reach land by traveling south over the sea rather than along the shore. To the extent that they followed a more direct route to their wintering grounds and were able to avoid predators, prevailing head winds, and lack of food to the west, those birds would have survived better than others of their population. Over time, this process could have created the fall migration far out over the Atlantic that Columbus encountered, barely in time, in 1492.

Today the curlews are almost gone, but their general route—across the Atlantic and Amazon to Argentina and back through central North America—is traced by American golden plovers. More than a million semipalmated sandpipers and other shorebirds reach the mud flats of eastern Canada, then fly across the ocean to similar flats in eastern South America. White-rumped sandpipers fly across later in the fall and may have been "birds of Columbus" along with curlews and plovers. "Gourmet" feeding sites are as vital to these birds as they were to Eskimo curlews. In spring, the mud flats of Delaware Bay swarm with horseshoe crabs depositing millions of eggs, which in turn feed thousands of such Canada-bound shorebirds as red knots. In autumn, the land around the Bay of Fundy is a feeding and staging site for more than a million sandpipers and plovers headed for South America. In the Western Hemisphere, as in the Old World, networks of such prime sites are being mapped and protected as integral links in migratory chains. If humans turn these areas into seaports, resorts, and power plants or pollute them with wastes or raise sea levels with atmospheric carbon dioxide, entire populations of birds stand to be eliminated.

In this quincentennial year of Columbus's voyage, if we were able to take to sea east of Bermuda in October to catch a glimpse of the transoceanic river of birds, we would see no Eskimo curlews. Other birds that Columbus saw now carry on, but perhaps not in such great numbers. Concerted international conservation measures can help insure that Columbus's river of birds does not become a river of no return.

Edwin O. Willis is an associate professor of zoology at the Universidade Estadual Paulista, São Paulo, Brazil.

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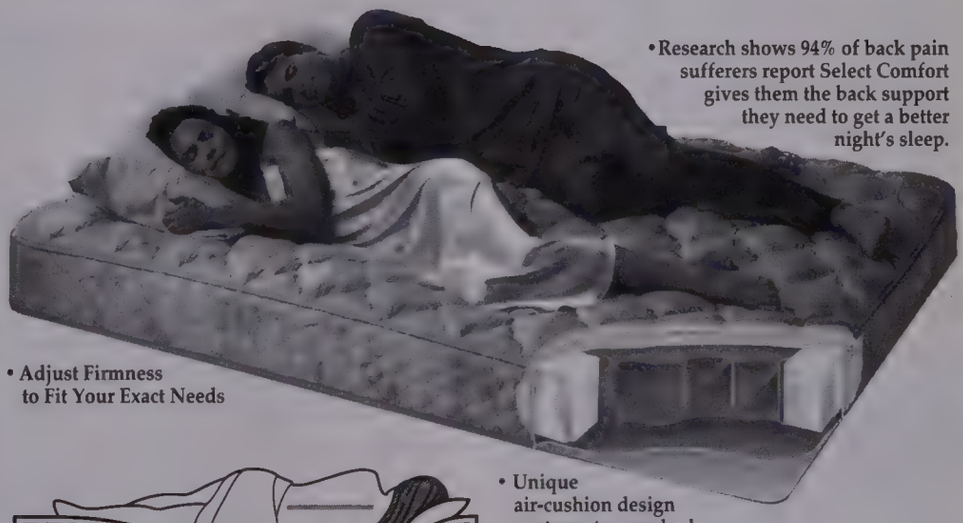

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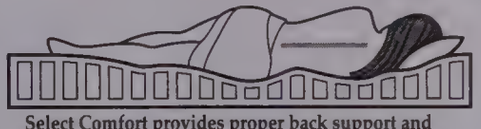

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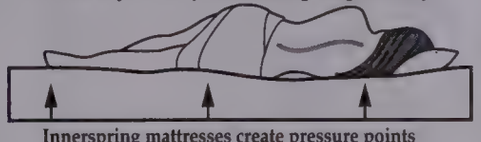

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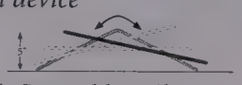

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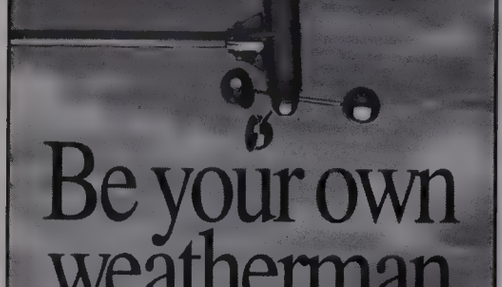

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Truth and Consequences

What you don't know can hurt you

Roger L. Welsch

Science and technology are wonderful things, but like other wonderful things—fire, for example—they can be used for harmful ends by some bad guy or may simply fall into the hands of some dummy who doesn't know their potential. Last summer, for example, I was burning tent caterpillars off some chokecherry bushes with a butane cigarette lighter and started a fire that burned twenty acres of grassland, the mail I was carrying into town at the time, and a little bit of my left foot. I wound up paying for that example of misapplied technology with a hundred-dollar donation to the Dannebrog Volunteer Fire Department, a painless penalty compared with my embarrassment when my wife, Linda, made me return the butane lighter to Slick at the tavern and tell him that if he ever gave me a lighter, matches, or anything ignitable again, *he* could donate a hundred dollars to the fire department. Oh, well. Look what Saddam Hussein did with his butane lighter in Kuwait.

Anyway, all at once a lot of people are worried about Soviet nuclear weapons technology falling into the wrong hands. Yes, we have much the same technology, and yes, we have had it for a long time, but we have known better than to use it (except twice). So it is up to us, the fifth or sixth most powerful nation in the world, to do what we can to head off disaster, whether intentional or accidental. Imagine Libya with long-range missiles, Iraq with The Bomb, or my mother with a Cuisinart!

But let's not waste our time with hypotheticals. I can relate a scientific horror story that will convince even the most wild-eyed techno-chiphead that we don't want a Technology "Я" Us free-for-all.

A few years ago, at an auction here in Dannebrog, Winslow Bender bought a polygraph—a lie detector. Don't ask me how a polygraph made its way out here where you can't even buy a movie ticket, but it was a polygraph all right, and Winslow, who can read a schematic like the rest of us read stop signs, knew what he had. It was small and primitive—the sort of apparatus used in high school labs—but it came complete with graph paper, pens, ink, and sensors to read galvanic skin response, respiration, temperature, and pulse. A bargain at two dollars.

Winslow took the device home, cleaned it up, plugged it in, and found to his amazement that he had a working lie detector right there on his kitchen table. The paper rolled out from under the pens as he tinkered with the sensors. He couldn't believe his good fortune: each and every one of them did what it was supposed to. He decided to take it up to the town tavern and show it off to Slick. Between the two of them, he reasoned, they should be able to figure out something to do with it.

Winslow took his prize to Slick, who agreed that nothing would be more fun in a small-town tavern than a lie detector. Winslow and Slick set it up on the bar, plugged it in, and that very evening started hooking up locals and asking challenging questions about their social lives. This generated a measure of instant hostility and resentment from which Slick's business has yet to recover, six years later. As it turns out, there are a lot of things more fun than a lie detector in a small-town bar. In fact, there's no room at all for truth in a

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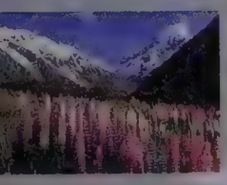

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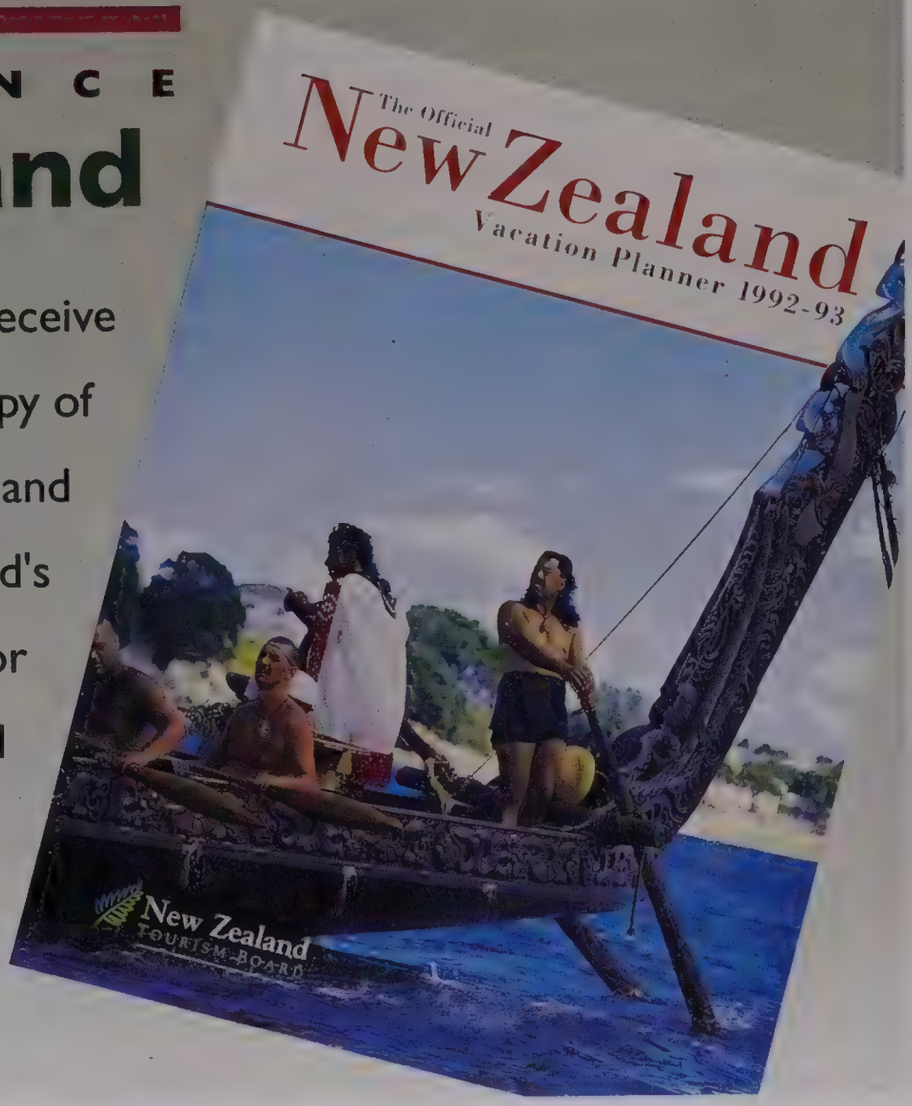

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small-town tavern. For instance, the sign above Slick's telephone reads,

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Just a minute, I'll get him = 10 cents
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He hasn't been in yet today = $1
Who? = $5

So then Winslow and Slick got another bright idea. They disconnected all the sensors on that machine except the respiration tube—a long rubber tube with an accordionlike device. The tube and accordion were designed to fasten around the victim's chest to measure the frequency and depth of his breathing. Winslow and Slick pulled the tube down behind the bar and nailed its end to the floor, out of sight of the customers. The plan was that they would talk some poor sap into taking a lie detector test. They would then hook up all of the old sensors—which now went nowhere except into a box with lots of dials and flashing lights—while the only thing governing the needles tracing inky paths on the rolling graph paper would be the rubber hose behind the bar, operated by Slick's foot.

Slick and Winslow planned to do the job up right, too. They would put petroleum jelly on the victim's wrists, carefully attach sensors, adjust dials, and flip switches off and on, convincing the sucker that he was really hooked up to a lie detector. They would even tell their victim that they first needed to calibrate the machine by asking some questions requiring straight answers and then a question to which they needed a false answer. Then they would perform the *coup de grâce* with a couple of nudges on the sensor tube behind the bar.

For several days Slick and Winslow rehearsed their script. It was going to be great. They figured they would pull this routine on every tourist who fell into their hands for the next twenty years.

Dreams do come true. The first customer stepping up to the glowing, humming, blinking machine on the evening of the grand unveiling of the Town Tavern's lie detector machine was CeCe, the abusive and abrasive waitress from over at the Chew 'n' Chat Cafe. Perfect. Slick moved behind the bar to the back of the lie detector machine, his foot resting lightly against the hose. Winslow attached wires and tubes to CeCe, told her to relax, moved dials, and checked gauges. He pushed a button, the machine hummed, and graph paper started to roll from under the machine's indicator pens.

Winslow intently asked calibration questions while Slick fine-tuned the machine. "What is your name?" Winslow asked loudly and deliberately, as if to convince the machine that this was all on the up and up.

"CeCe Steffenhausen."

The pens didn't waver and black lines flowed out onto the paper, straight and true. "What is your husband's name?"

"Carl Steffenhausen."

Not a quiver, not a wiggle in the inexorable lines.

"What is your age, CeCe Steffenhausen?" And under his breath, Winslow whispered, "Remember, CeCe, lie on this one so we can be sure the machine is working." By now a sizable crowd had gathered.

"Sixteen," she straight-faced. And as if

y magic, the needles leaped into agita-
ion, the lines on the graph paper forming
viggles, peaks, and valleys. Out of the
orner of his eye Winslow saw Slick move
ver so slightly as his foot kicked at the
ose under the bar, but CeCe and every-
ne else in the tavern were so mesmerized
y the performance of the polygraph that
lick probably could have reached down
nd batted the respiration hose with a ten-
is racket and no one would have noticed.

The crowd murmured. It was impres-
ive, all right. "Okay, let's get on with the
est itself," Winslow said gravely, adjust-
ng a couple of dials. "Ready, CeCe?"

"Ready." She stared intently at the ma-
hine and the now quiet indicator pens.

"How many children do you have?"

"Three."

Not a ripple.

"Names?"

"Tiffany, Phillip, Martin."

Six arrow-straight lines.

Winslow claims he doesn't know what
ame over him—maybe it was CeCe's en-
hantment with the machine, maybe it was
he excitement of the crowd, maybe it was
imply a matter of technology and science
alling into the wrong hands—but what-
ver the reason, the next question he asked
was, "And are those children all Carl's?"

CeCe sputtered, "Of course, Winslow,
ou idiot," while at that very moment
lick started kicking the tube under the bar
s if he were stomping out a grass fire. The
eedles on the paper went crazy. The mob
gasped, and CeCe stared with disbelief
nd growing fury at the mountain ranges
nd grand canyons springing out from
nder the polygraph's violently jerking
ens. She leaned over the bar, right over
he twitching pens, and shouted at them,
Well, to the best of my knowledge!" The
eedles went still and the lines again fell
lat on the graph paper. CeCe raged out of
he bar to the cheers of her audience.

Later that evening Carl Steffenhausen,
who is about as big and ugly as a threshing
machine except without the safety fea-
ures, dropped by the tavern and had a
conversation with both Winslow and
Slick. That polygraph is still sitting at the
end of the bar in Slick's tavern, unused for
nearly six years now except to hold the
lost-and-found box.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska. His latest book, Touching the Fire: Buffalo Dancers, the Sky Bundle, and Other Tales *(Villard Books, 1992), explores rites, objects, and places sacred to Native Americans.*

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Lamotius and His Marine Marvels

The Dutch commandant of Mauritius was a disastrous governor but an artist-naturalist of rare talent

by Theodore W. Pietsch and Lipke B. Holthuis

Among the world's forgotten treasures are the rare and delicate paintings of Indian Ocean animals created three centuries ago by the troubled governor of Mauritius, Isaäc Johannes Lamotius (ca. 1645–1718). Well educated for his time, Lamotius was a student of history, art, botany, medicine, and theology who was chosen by the Dutch East India Company to run a small part of its colonial island enterprise. Isolated from his former intellectual life in Holland and struggling for fifteen years to govern the small, unruly band of Dutch colonists, Lamotius consoled himself by studying the biota of the island, then practically unknown to European science.

During his first year as governor, Lamotius thoroughly explored the perimeter of Mauritius on foot and made several excursions into the interior. Later, he discovered a plateau in the island's center and charted a relatively detailed map. Using crude instruments, he correctly estimated the circumference of the island, about 180 miles, and compiled a long list of indigenous medicinal plants. But his greatest interest was the marine creatures, which he devoted his spare time to observing and documenting. Two hundred and fifty-one colored drawings survive; there were probably many more. These illustrations, unpublished until now, are superior both scientifically and artistically to most efforts of his contemporaries. They are the earliest known descriptions of the marine biota of Mauritius and the pioneering studies of any Indo-West Pacific habitat.

Although they are mentioned in several early nineteenth century books, Lamotius's paintings were wrongly attributed to Cornelis de Vlamingh, who owned them at one time. We now know that de Vlamingh, an employee of the Dutch East India Company, was only a young boy when the artworks were made. After Lamotius's death, they passed through a series of owners and eventually were contributed to the archives of the Bibliothèque Centrale, Muséum National d'Histoire Naturelle, Paris, where the great French zoologist Georges Cuvier studied them. (He mentioned their existence in the first volume of his *Histoire Naturelle des Poissons,* published in 1828, but by then the credit for their authorship had been shifted to de Vlamingh.) They had been in that archive for a century and a half when one of us, Lipke B. Holthuis, tracked them down in 1959, during his scholarly sleuthing into the history of early ichthyological illustrations. After a detailed comparative study

Distinguished by its alternating yellow and blue stripes and its hooked tail fin, the lined surgeonfish ranges from the coast of East Africa to the central Pacific.

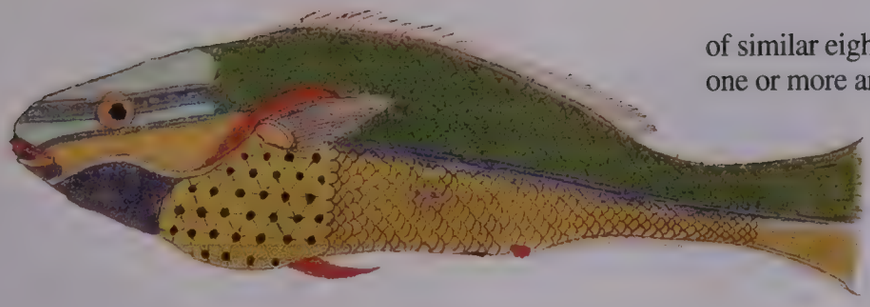
The widely distributed clown triggerfish prefers coral-rich areas of outer reef terraces adjacent to steep drop-offs.

Usually solitary, the regal angelfish, ranges across the tropical Indo-Pacific. Difficult to maintain in captivity, those few that survived the long trip to Amsterdam in Lamotius's time were placed in porcelain jars and given as prized, if ephemeral, gifts.

Photographs courtesy of the Bibliothèque Centrale, Muséum National d'Histoire Naturelle, Paris

Extremely wary, the raccoon butterflyfish swims alone, in pairs, or in aggregations of up to twenty individuals. Widespread throughout the Indo-Pacific, its range extends as far east as Hawaii.

Sand stargazers frequently bury themselves in sandy bottoms, exposing only their upturned faces and stalked eyes as they wait for small prey to swim by.



Named for the island group on which Lamotius was imprisoned, the Banda wrasse is found in abundance there.

of similar eighteenth-century works, Holthuis concluded that one or more artists had made multiple copies of Lamotius's drawings and that some of these were copied again and again. The third- and fourth-hand versions were far removed from the scientifically astute renderings of Lamotius's originals; when some of the diluted, derivative works were later published, critics blasted them as exaggerated, crudely drawn, and barbarously colored (*see* "Louis Renard's Fanciful Fishes," *Natural History,* January 1984).

We do not know if Lamotius had decided beforehand to pursue the island's natural history when he arrived at Mauritius with his wife and daughter in September 1677. The former commandant had retired, and the new governor had high hopes and detailed plans for bringing prosperity to the island. All the elements for success seemed to be at hand—fertile and easily cultivated soil, plenty of stone and wood for construction—but despite good intentions and hard work, almost everything Lamotius attempted went wrong.

His first act was to order the clearing and replanting of the company's garden, which the former administration had allowed to fall into disuse. By August 1678, the crops were doing well, but before they could be harvested they were completely destroyed by locusts. In December 1677, Lamotius began construction of a dam on the Nyon River, in order to have a reservoir of water to operate a proposed sawmill and tannery. Soon completed and in full operation, the water-powered sawmill began producing boards for export but was stilled by an extraordinary drought. The tannery was also successful at first but was destroyed by a hurricane; the colonist assigned to its operation gave it up and turned to agriculture.

Natural disasters took their toll, but human discord ultimately ruined Lamotius. In 1677, the Mauritians numbered about 135; by 1679 there were 153, including 28 employees, 63 slaves belonging to the company, 6 exiled persons, 43 free colonists, and another 13 slaves belonging to the latter. According to Albert Pitot, writing in his *T'Eylandt Mauritius* (1905), the colonists were, for the most part, undisciplined and easily discouraged from productive labor by storms, floods, droughts, and the depredations of caterpillars, grasshoppers, and vermin. As one witness, former governor of the island Hubert Hugo, described it, the hordes of rats alone must have been enough to destroy any human initiative:

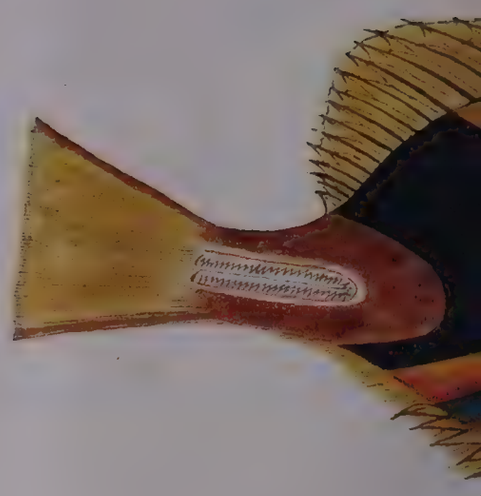
> They set up their headquarters in the roofing of the lodge under the palm branches. At night they came down to the granaries in their myriads, eating and making such a racket that no one could sleep. They even came down into the bed chambers to sample the Dutchmen, biting their hands and feet and running all over them. Arsenic was resorted to, and in the morning, their dead bodies were collected by the basketful, fallen from the roof and lying on the ground the distance of a gunshot from the lodge. The more they were killed, the more they came on. After two or three days, the roofing had to be replaced because of the abominable smell.

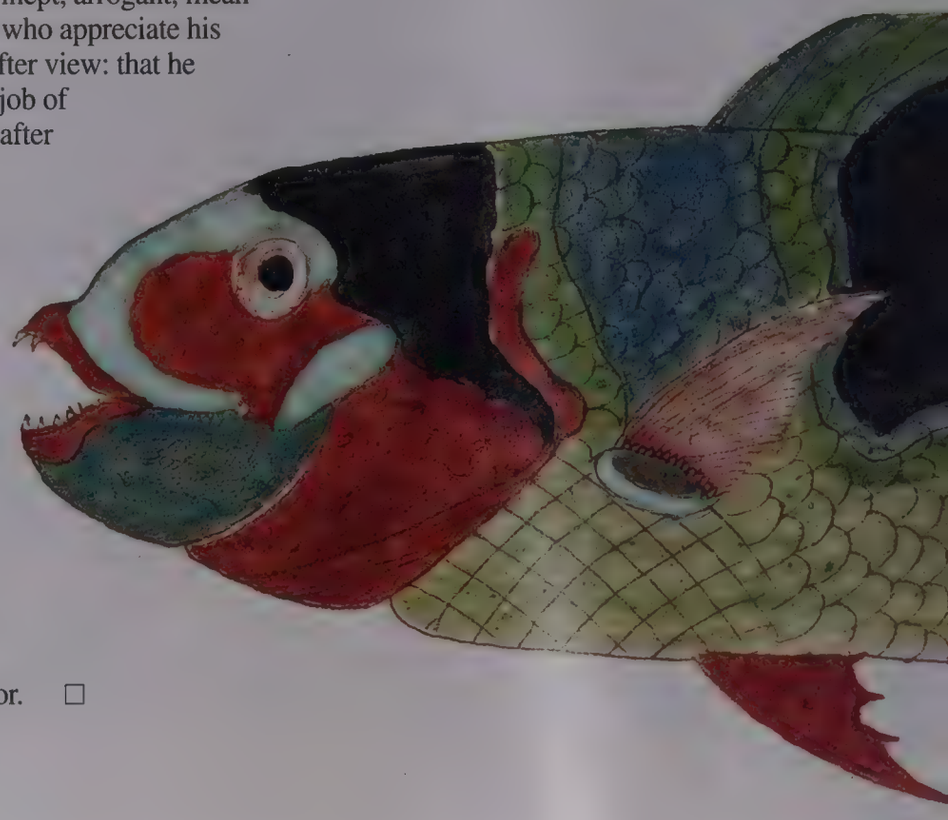
Later in his rule, Lamotius became tyrannical, but at the beginning he was quite friendly with the colonists, dining and drinking with them daily. Against company regulations, he allowed them to supply maize, tobacco, and butter to English sailors, who paid higher prices than the Dutch, with whom they were supposed to trade exclusively. In 1679, a fire broke out in the fort that claimed the lives of Lamotius's wife and daughter. After this personal tragedy, he grew despondent and began to viciously attack his subordinates for their real or perceived laxity. Punishment for infractions became severe, and colonists who defied the governor found their houses or plantations burned down. In 1689, during a drunken brawl with Abraham Steen, one of his chief subordinates, Lamotius almost stabbed the man to death.

Although his reports and surveys had been well received by his superior, the governor of the Cape of Good Hope, Lamotius was removed from office in 1692. So many people had sworn out complaints against his violent, repressive rule that he was sent in chains to Batavia (present-day Jakarta, Indonesia) for trial. There, in 1693, he was accused of having treated colonists and employees harshly and unjustly and of currying favor with his English competitors. Execution was a real possibility, but instead Lamotius was deprived of his position, rank, and salary and condemned to forced labor on the island of Rozengain in the Banda Archipelago, a small island group in the south-central Moluccas.

After serving his six-year sentence, Lamotius went to South Africa, where in 1718 he petitioned the governor and the council of the Cape of Good Hope to allow him passage back to Holland on a company ship at his own expense. The request was granted, and Lamotius left the Cape on April 7, 1718. His end is uncertain; he may have been buried at sea during that homeward voyage.

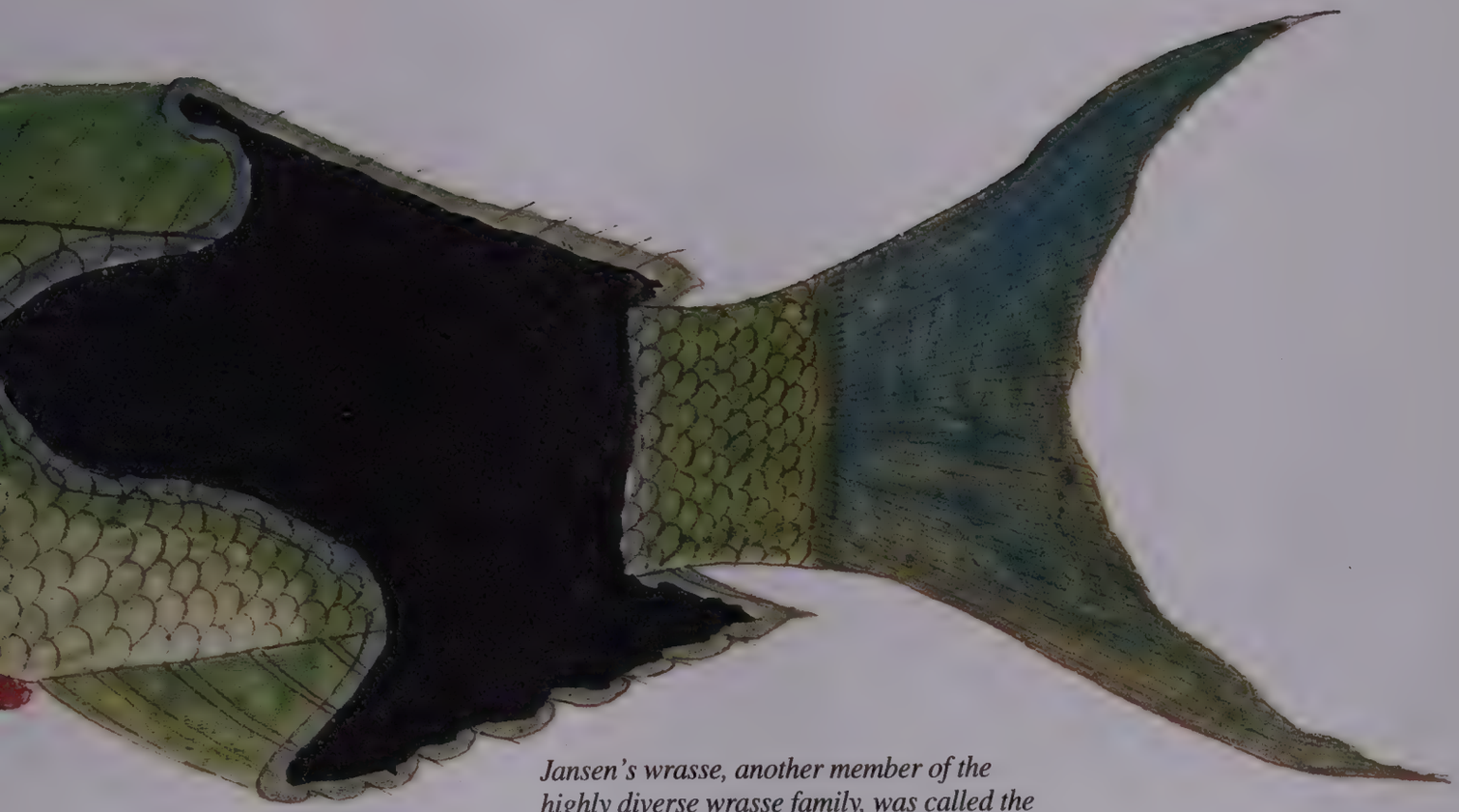
Some historians have written off Lamotius as an inept, arrogant, mean-spirited character deserving of few kind words. We who appreciate his artistic and scientific contributions tend to take a softer view: that he was ill prepared and inappropriately chosen for his job of governor; that reverses, failures, and personal grief after losing his family got the better of him; and that he turned to his love of nature for solace from the impossibility of his situation. One measure of Lamotius's spirit is that even during his darkest moments he continued to paint the beautiful fishes and marine invertebrates of Mauritius. Dates inscribed on various illustrations show that even after his forced removal from office and while in transit to Batavia, where he faced imprisonment or death, he still continued to observe and to paint. Lamotius surely deserves credit for a remarkable scientific and artistic accomplishment, made at a time when the vast majority of his contemporaries saw little or no value in his endeavor. □





The black-belt wrasse, also called the split-level hogfish for its two-tone color pattern, ranges from the tropical western Pacific east to Fiji.

Sometimes called the white-banded, or lagoon, triggerfish, this species is common throughout the tropical Indo-Pacific. It sleeps on its side and produces a loud, whirring noise when startled.



Jansen's wrasse, another member of the highly diverse wrasse family, was called the saddle fish by Lamotius's contemporaries.

Hunters returning to the ice-bound shores of Little Diomede Island, in the Bering Strait, can easily pull their umiak out of the water and carry it across the ice to the village. The ice is stained pink where walrus and seal meat were unloaded after previous trips.

Last of the Umiaks

For hunting walrus among the ice floes of the Bering Strait, the Inuit's spacious and resilient skin-covered boats have no equal

Text and photographs by Fred Bruemmer

The umiak is nearly extinct. Fewer than 100 survive "in the wild," and only about a dozen dull, dusty specimens can be found in the museums of the world. Once its range was immense: from eastern Siberia to East Greenland. The spacious, seaworthy skin boat of the Inuit and their arctic neighbors, the umiak was the perfect boat for whaling and walrus hunting in the ice-choked, storm-haunted seas of the north. The boat's size permitted trade and migration, linking continents and cultures. "After the umiak was invented," wrote anthropologist Dorothy Jean Ray, "the [Bering] Strait became an intercontinental highway, its coastal fringes occupied by peoples who had more or less the same way of life." Today the umiak is used only in a few localities on the coasts of Alaska and Siberia.

Capt. Frederick W. Beechey of Britain's Royal Navy saw umiaks in 1826 on Little Diomede Island in the Bering Strait and took a sailor's delight in these craft, which were "both light and pliable and very safe and durable." In 1879, the Swedish explorer Nils A. Nordenskjöld admired the *baidar* (the Russian name for the umiak) used by Siberia's Chukchi: "It is so light that four men can take it upon their shoulders and yet so roomy that thirty can be conveyed in it." Above all, the umiak was superbly safe and seaworthy in waters where boats often become trapped in the ice. In the Arctic, "which is a graveyard of broken boats," noted Dorothy Jean Ray, "the Eskimo umiak has proved its superiority over all other boats time and again."

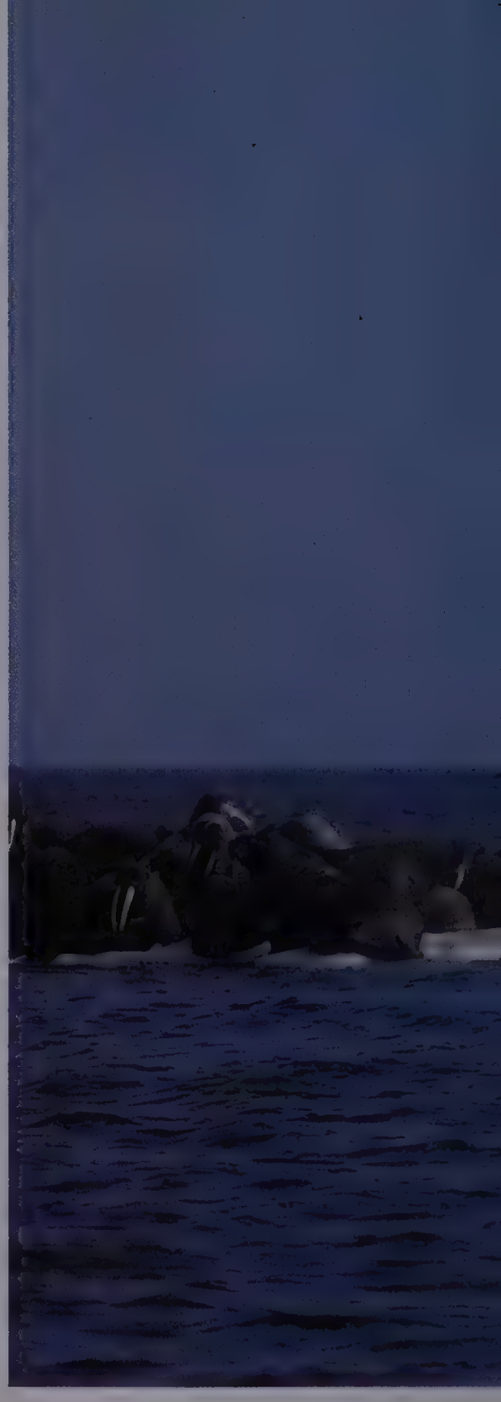
I quickly learned to admire the strength of umiaks and the skill of their crews when I lived for three months on Little Diomede Island in 1975. In late May, we were far out in the Bering Strait hunting walruses, which often rest on the ice as they migrate north. A storm surprised us, and suddenly we were caught in a maelstrom of churning floes in the wind- and current-driven pack. Leaping in and out of the boat, the men poled and hauled the umiak through cracks in the ice. Jagged floes rasped against the boat's walrus-skin cover, causing the flexible frame to buckle but not break. When we reached a stretch of open water, the captain (umialik) of the boat gunned the 40 hp motor and raced toward the largest floe. Our bow hit the edge of the ice at full speed, and the crew and I jumped from the rearing thirty-foot boat and pulled it down and forward onto the safety of the floe. "Relax," the umialik, Tom Menadelook, told me with a reassuring smile. "We have never lost a boat." The boat was our home and shelter as we drifted northward toward the Chukchi Sea for two days until the ice opened up again.

When I returned to Little Diomede fifteen years later to spend another two months during the walrus-hunting season, many things had changed, but the umiaks and the spirit of their crews had not. The population of Ignaluk, the small village tacked to the base of the island's soaring mountainside, had grown from 119 to 171, but the number of umiaks remained unchanged: three 18-foot craft used mainly in spring to hunt ringed seals and bearded seals near the island, and four 30-foot umiaks used primarily for the long and risky walrus hunts in May, June, and early July and again, briefly, in fall when some 200,000 migrating walruses funnel southward through Bering Strait. The umiak and the seal and walrus hunts were still the basis of Inuit life on Little Diomede, as they have been in much of the Arctic for at least 2,000 years.

No umiak remains that old have ever been found, but whaling and walrus-hunting implements of that age have been found at archeological sites on both sides of the Bering Strait. Because such hunts would have been impossible with the smaller kayaks, umiaks or similar boats were probably in use 2,500 years ago, and perhaps much earlier. From this core area they spread east as far as East Greenland. Although in historical times there were variations in the style and size of umiaks in different regions, the essential shape and design were similar along more than 7,000 miles of coast. The Chukchi "atkuat," or *baidar,* "corresponds completely with the Greenlander's umiak or woman's boat," Nordenskjöld noted in 1879. In 1949, the Danish archeologist Count Eigil Knuth found a remarkably well-preserved umiak on desert-dry Peary Land at the northern tip of Greenland, less than 500 miles from the North Pole. This umiak was thirty-one feet long, and its driftwood frame was lashed with baleen. It had been built in about A.D. 1440, and in size, design, and workmanship it was nearly identical to umiaks used 400 years later by Greenland's people.

Skin boats were not unknown in Europe. Small round ones, called coracles, had been used since prehistoric times on British lakes and rivers, and a few still existed in remote regions of Wales when I lived there thirty-five years ago. The Irish used large, boat-shaped curraghs, their light wooden frame covered with oak-tanned oxhide, the double-sewed seams coated with tallow. Similar canvas-covered curraghs were used by the basking

Crews prepare their umiaks for a walrus hunt, below. On a rare clear day, right, the hunters approach an ice raft loaded with walruses. Because the animals sink after they are killed, the Diomeders hunt them on the ice floes.



shark hunters of Achill Island, Ireland, with whom I spent the summer of 1960.

The first umiak known in Europe drifted across the North Sea in about A.D. 1400 with, according to a contemporary writer, a "kind of pygmies in it"; this boat hung for years in the Nidaros (now Trondheim) Cathedral in Norway. In his *Historia de gentibus septentrionalibus* (History of the Nordic people), published in Rome in 1555, the Norwegian bishop Olaus Magnus knew that "the inhabitants of Greenland are extremely good at sea; they use skin boats which are very safe." Dionyse Settle, the Elizabethan chronicler of explorer Martin Frobisher's second expedition to Baffin Island, observed of the Inuit in 1577:

> They have two sorts of boats made of leather, set out on the inner side with quarters of wood, artificially tyed with thong.... The greater sort are not much unlike our wherries, wherein sixteene or twenty men may sitte; they have for a sayle, drest the guttes of such beasts as they kill, very fine and thinne, which they sewe together.

Umiaks ranged in size from ten-foot craft used in Labrador for hunting in sheltered fiords to sixty-foot boats with a twelve-ton carrying capacity used in Greenland 250 years ago. The typical umiak was thirty feet long with a five- to eight-foot beam and a depth of three to four feet. It was flat bottomed throughout its range, sharp ended in the western Arctic, and boxlike, with square stem and stern, in the eastern Arctic. While it lacked the grace and spirit of its sister craft the kayak, the umiak was a stout and buxom boat, roomy and safe.

The umiak frame was made of driftwood, a rare and precious commodity in large parts of the Arctic. Stem and stern were usually scarfed and treenailed with bone or ivory pegs. Chines, stringers, and ribs were lashed with seal thong or, where available, with bowhead baleen, the ideal material, for baleen neither expands nor shrinks when wet, maintains flexibility, has great tensile strength, and never rots.

The strongest, most durable covers were made, where available, of split walrus hide or of bearded-seal skins. The Aleuts used sea lion skins to cover their large *baidar*s; the Mackenzie Inuit were beluga hunters and covered their umiaks with beluga hide; on the West Greenland coast harp-seal skins were used when bearded-seal skins were not available; and the Inuit of East Greenland often used the skins of hooded seals. The finished craft was light, buoyant (empty it had a three- to four-inch draft), strong, and flexible. It could carry thirty to forty people or about five tons of cargo. In emergencies, tears in the skins were temporarily plugged with pieces of blubber until the damaged boat could be pulled out of the water and properly patched. Such mishaps were rare, however—a close encounter with an enraged walrus is about the only thing that can rip through the umiak's skin. (This danger to the craft is so great that during one of my trips, one of the crew chose to shoot at an attacking walrus through the bottom of the boat. The shot, which passed a foot or two from my legs, put a small hole in the bottom of the boat but may have saved it from more serious damage.)

According to the Little Diomeders, their umiaks are virtually unsinkable. They routinely go hunting in stormy weather (calm days are rare in the Bering Strait). A yard-broad waistcloth of canvas (formerly sealskin), normally furled against the gunwale, is raised on stout stanchions or on paddles during a storm to keep the spray out. In the past they also lashed inflated sealskin to the umiak's side as sponsons. In the 1870s, Smithsonian

ethnologist Edward W. Nelson noted that "with their boats fitted in this manner these people sail fearlessly along their stormy coasts."

For sailing in open waters the umiaks were often equipped with a simple square sail with grommets and blocks carved of ivory. In the Aleutian Islands the sails were fashioned from densely woven grass mats. Elsewhere, scraped seal, caribou, or reindeer skins or, more frequently, four-inch-wide cleaned, translucent, sewn-together strips of bearded seal or walrus intestine were used. Capt. George F. Lyon of the HMS *Griper* bought such an "ingeniously constructed sail" in 1824 from Hudson Strait Inuit for a knife. The sail was nine feet broad, thirteen feet high, and weighed three and three-quarter pounds.

In 1881, Nelson met a flotilla of boats near Alaska's Cape Prince of Wales and wrote: "The umiaks in full sail, crowded with fur-clad people, dogs, and their various possessions made a very picturesque sight." Explorers were often astounded by the volume and variety of cargo carried by umiaks. While Captain Beechey watched in 1826, Alaskan Inuit unloaded from two umiaks "fourteen persons, eight tent poles, forty deer skins, numerous skins [bags] of oil, earthen jars for cooking, two living foxes, ten large dogs, bundles of lances, harpoons, bows and arrows, a quantity of whalebone, skin bags full of clothing, some immense nets made of hide for taking small whales and porpoises, eight broad planks, masts, sails, paddles, besides seahorse [walrus] hides and teeth" and many other articles.

In 1990, "my" Little Diomede umiak carried two outboard motors (55 hp and 30 hp), eight 5-gallon tanks of gas and one 50-gallon drum of gas, eight hunters and me, nineteen guns, harpoons, great red plastic floats, two axes, an ice chisel, patches of leather and thong to repair the boat, a large tool chest, paddles, poles, gaffs, two marine compasses, coils of rope and thong, food for many days, pressure stoves, and waterproof sacks with spare clothing, and if the hunt was successful, we returned to Ignaluk with two or three tons of walrus meat and ivory, piled onto large plastic sheets dubbed "white man's sealskins," for until recently sealskins were used for this purpose. When the hunters return to the village, the meat is dried or stored in holes dug in the permafrost, where it remains frozen. Once the hunts supplied the islanders with nearly all their food, but now only about half of their diet is walrus or seal meat.

Originally the umiak was probably both hunting boat, stealthily paddled or sailed by men, and traveling boat, noisily rowed by women. As whale hunting declined,

The skin of a newly covered umiak, right, glows golden yellow. In 1975, Eva Menadelook, below, cut blubber from a walrus skin. Fifteen years later, far right, she has mastered the technique of splitting the walrus skin into equal halves.

umiaks in Canada's eastern Arctic (in historical times no umiaks were used in Canada's central Arctic) and in Greenland became increasingly women's boats—so called, said the Greenland missionary Hans Egede in 1745, "because the women commonly row them. For they think it unbecoming a Man to row such a boat." Consequently, wives as rowers were in demand. In East Greenland, the ethnologist Gustav F. Holm noted in the 1880s, "A second wife is sometimes taken in order that the husband may always count on having two rowers for his boat."

Inuit women were strong, enduring rowers who often sang while they rowed. The explorer-writer Peter Freuchen, young, naïve, and chivalrous, offered to spell one of them at the oar and reported, "But a couple of hours of the pace set by the girls left me exhausted." The women rowed on for thirteen hours, then attended a party in the evening "and danced for five hours." Migrations by the umiak could be extensive. The Canadian Inuk Joe Talirunilik described in 1965 how in the 1890s his people from the Povungnituk region of eastern Hudson Bay had searched for a better life. Some forty men, women, and children and all their belongings crowded into one umiak and wandered for two months until they came to the uninhabited Ottawa Islands. They lived there for several years and then returned with their faithful umiak to the mainland.

In the nineteenth century, other boats—dories, whaleboats, and large canoes—began to supplant the umiak. By 1820, the umiak was extinct in northern Hudson Bay. Between 1861 and 1876 the number of wooden boats in northern Labrador increased from 117 to 237, while the number of umiaks decreased from 14 to 4, and by 1916 the umiak had ceased to exist on the Labrador coast. It vanished from Baffin Island early in this century. There were 251 umiaks in West Greenland in 1880 and 339 in 1900, but after the turn of the century they rapidly declined. The last one, used for a final hunting trip in 1966, is now in a museum. The last East Greenland umiak was used in Angmagssalik until 1970. The umiak then became extinct in the eastern Arctic.

The whaleboat, often traded by whalers to Inuit for baleen, ivory, or services or sold to the natives, replaced all umiaks on Saint Lawrence Island in the Bering Strait early in this century. But then the whaleboat died out (the last fully equipped whaleboat was built in 1933 and sold to a museum), and the Saint Lawrence is-

landers reverted to the traditional but somewhat changed umiak. Little Diomede Island, with its boulder beach and pounding surf, was death to wooden boats, and the whaleboat was never adopted there. But the Diomeders and other native Alaskans did copy the round-bottomed design of the whaleboat, and oval umiak ribs are now made of steam-bent hardwood, instead of driftwood. These were the only major changes in umiak design in more than 2,000 years.

In coastal areas of Alaska and Siberia, where the umiak originated, the boat persists but its numbers are dwindling. One last umiak remained in Shishmaref, Alaska, in 1968, its driftwood-ivory-whalebone frame built by Diomeders at least forty years ago. Now it is gone. Wales, Alaska, had fifty-one umiaks in 1891, four when I visited it in 1975, and none when I returned in 1990. In addition to Little Diomede Island and Saint Lawrence Island, only the Inuit in Point Barrow and a few other Alaskan settlements still use umiaks to hunt whales and walruses among the ice floes.

On the Siberian side there are seven *baidar*s in Sireniki, a walrus-hunting settlement, and a few in other villages, "but they are poorly made," according to sev-

The captain of an umiak, right, repairs a cracked rib in his boat. Below: Hunters stop for a lunch break along the rocky coast of Little Diomede Island.

eral Diomeders who have visited Siberian Inuit. One problem with the boats seems to be that in Siberia, the all-important splitting of the walrus hide, traditionally a woman's job, is done by men, and the result, say the Little Diomede women with a certain superior glee, is deplorable.

The Little Diomeders are traditionalists; they tend to think highly of themselves and their umiaks. Skills and positions are passed on from generation to generation. In 1975, Tom Menadelook, Jr., then eleven, spent the first hunting season in his father's umiak, shot his first seal, and then brought pieces of it to every household in the village, including my cabin, thus symbolically becoming the ideal Inuit man: one who shares and provides. In 1990, Tom, Jr., now twenty-six, was umialik of the Menadelook boat, and most of the crew were young men. All were excellent hunters, although perhaps less daring than their elders, who were famed as "Vikings of the Arctic Sea."

Umiak skeletons, when well built, last a long time. The skeleton of John Iyapana's boat on Little Diomede was thirty-seven years old in 1990; the one of the Ozenna clan (boat crews are made up, in general, of close relatives) was "at least" fifty years old. The other two skeletons, belonging to Albert Iyahuk and Tom Menadelook, had been built in 1974. They are made of steam-bent hardwood and took about three weeks to construct.

While the frame is long lasting, the walrus-skin cover has to be replaced every two to three years. To prevent the porous skin cover from becoming waterlogged, umiaks are frequently and liberally smeared with seal oil. Despite that, covers slowly rot and weaken and are no longer strong enough to withstand the cutting new ice or the grinding floes.

To cover the eighteen-foot umiaks, three walrus skins are needed, and five split skins are required for the thirty-foot umiaks. Only the smooth skins of females or young bulls are used; the skins of adult bulls are too heavy, scarred, and warty. First the blubber is removed from the skin, and then begins the exacting task of splitting the two-inch-thick walrus hide into halves of equal thickness. The women sit on the ground or on a low bench or stool, drape the skin over a well-anchored oval board, and slice it in half with smooth, even strokes of the razor-sharp *ulu,* the crescent-shaped woman's knife.

When all the skins required for a cover are split, they are soaked for several days in seawater, depilated and thoroughly cleaned, and carried into Ignaluk's community hall to be sewed together. Most women in the village help, including two nuns of the order of the Little Sisters of Jesus—Sister Nobu, originally from Japan, and Sister Damiene, originally from Alsace, France. Both have lived on the island for many years and are highly respected walrus-skin splitters and sewers. The skins are sewed together with the "lost-stitch" technique, a double seam in which the needle does not pierce the skin from one side to the other. Braided reindeer sinew was used as thread in former days; now, waxed and soaked in seal oil, heavy cotton twine is used. Only the leader is still made of sinew, so that needle and thread can slip more easily through the exceedingly tough walrus skin.

Skin-cover sewing is a social affair. The umialik provides meals and endless tea and coffee for all the people, and in about ten hours of sewing the umiak cover is finished. Men stretch the still moist and supple cover over the umiak frame and lash it to the skeleton, now usually with heavy nylon rope, in the past with walrus thong which anthropologist Froelich Rainey has called "the strongest line known before the invention of the steel cable." Already taut when wet, the cover becomes drum-tight as it dries upon the frame.

The Diomeders are proud of their umiaks and say they will never abandon them. But in 1978 the first aluminum boat came to the island, and now several are used. So far, they are mainly "fun boats," good for quick hunts in open water, but because they tip easily and the metal is readily torn on rocks or ice, aluminum boats are dangerous in storms and among floes. In really dangerous conditions, the umiak has no equal, but despite its long tradition and excellence, fewer and fewer are being used in Alaska and Siberia, and its epitaph may well be the little Inuit song the ethnologist William Thalbitzer collected in West Greenland at the beginning of this century:

My darling umiak
Now always on land, how deplorable!
About to fall in pieces.

Seeing Red

Why does the horned toad cry tears of blood?

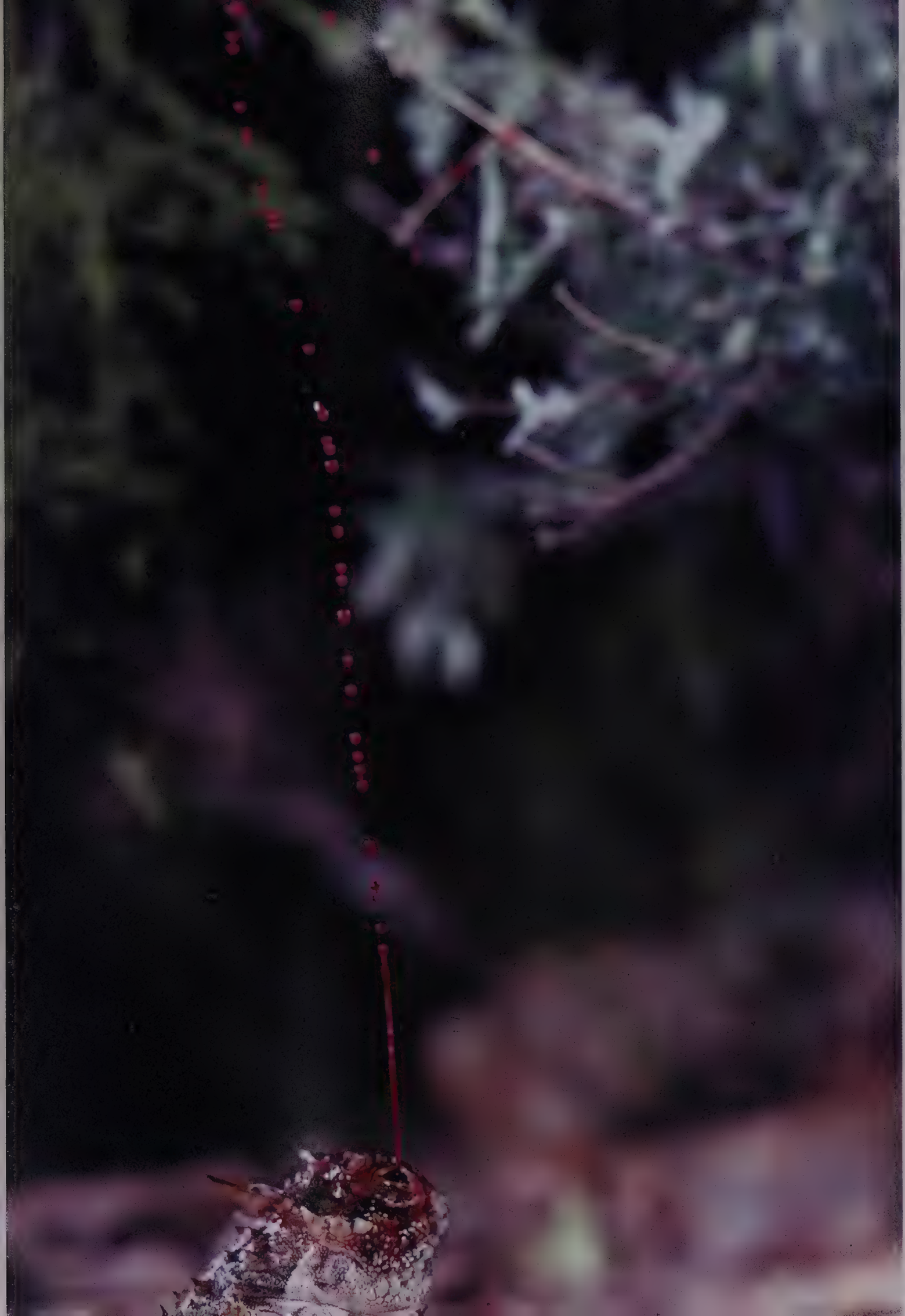
Photographs by Raymond A. Mendez

Not really a toad at all, the horned toad of the American Southwest is a small, flat-bodied lizard related to iguanas. Its docility has made it a favored pet, but for 120 years, its bizarre behavior has been cause for controversy. Cowboys and countryfolk swore they had seen the creature shoot long streams of blood from its eyes; others dismissed such accounts as tall tales.

In 1871, the earliest written account of blood squirting was published by the noted naturalist Alfred Russel Wallace, quoting a letter from his brother John: "Under certain circumstances, apparently as a means of defense, this creature squirts out from one of its eyes a jet of bright-red liquid very much like blood. This I have observed three times from three different individuals, although I have caught many that did not do it." During capture, only about 5 percent of the lizards will squirt. Over the years, scientists have tried to correlate this behavior with sex, season, temperature, or other factors—without notable success.

Recently, however, George Middendorf, of Howard University, and Wade Sherbrooke, of the American Museum of Natural History, made an interesting discovery while working at the Museum's Southwestern Research Station in Portal, Arizona. With the help of Dusty, a yellow Labrador retriever, they found that dogs can consistently elicit blood squirting by the lizards, while rough handling and mock attacks by humans cannot. Other variables appeared not to matter; whether it was day or night, hot or cold, the lizards consistently sprayed blood only in response to Dusty's threats. Surprisingly, they did not shoot blood during attacks by roadrunners or grasshopper mice.

Sherbrooke and Middendorf now believe that blood squirting by horned toads, documented for the first time in these photographs, is a specific "anticanid" defense. They plan to make further tests with foxes and coyotes, which are among the lizards' natural enemies.—*R. M.*



Basque shepherds move their flock on an Idaho ranch. The trek, from summer pasture in the mountains to winter range at lower elevations, can take a week.
John Baker

The Whistle Heard Round the World

Humans and working animals around the globe have developed their own Esperanto

by Patricia B. McConnell

I came back to consciousness encircled by anxious Mexican stockyard workers. In spite of my bleary state and limited Spanish, the rapid-fire speech of the onlookers clearly conveyed to me their rising panic. Exactly what should they do with an unconscious middle-aged woman, laden with tape recorders and cameras, who had just been knocked out cold by a goat? Trying to reassure them in English they could not understand, I gathered my muddy equipment and attempted to stroll scientifically away.

Locking horns with a billy goat was not the scenario I had in mind in my carefully ordered plan to research how professional animal trainers use sound to signal their domestic animals. But since that incident, I have successfully recorded the acoustic signals used by more than 100 professional animal handlers. I call this my Dr. Doolittle project, after the character of children's fiction who learned to "talk with the animals." Since professional animal trainers must be able to communicate effectively with animals to make a living, I suspected they had much to teach scientists about how animals respond to different sounds. In my research, I tried to discern universal patterns in both the way we communicate with animals and the way animals communicate with one another; patterns that could be used to further our understanding of animal communication and perhaps even shed some light on the development of human language.

The project grew out of a study I began at the University of Wisconsin-Madison when ethologist Jeffrey Baylis suggested that I look into a naturally evolved system of communication between species—that of shepherds and their sheep-herding dogs. I located one of the country's best-known sheep-herding dog trainers and handlers within an hour's drive of Madison. Jack Knox raises and trains border collies, a breed of wily working dogs from Scotland that manage more than two-thirds of the world's sheep.

With a minimum of direction from their handler, domestic ducks, below, negotiate a street in Yunnan Province, in the People's Republic of China. Opposite page: A team—man and border collie—compete in international herding dog trials in Alnick, England, near the Scottish border. The maneuver, splitting several sheep off from a flock, is a practical task on the farm.
Franz J. Camenzind

Border collies are intense, effective livestock herders. When working, they neither bark nor bite, unless challenged by a recalcitrant herdee. Instead, they control the movement of livestock by assuming the stalking posture of a predator. Just as a domestic cat lowers its head and tail and crouches as it sneaks up on a sparrow, border collies approach sheep with head and tail lowered, body crouched, and most importantly, a direct and intense stare. Herd animals interpret this as a hunting posture and first flock together (for safety in numbers), then move away. A well-bred and well-trained border collie is able to work at the exact distance necessary to move the stock forward without panicking the herd into a run or challenging individuals to stand and fight. Because the dogs rarely take their eyes off the sheep, handlers rely on sound rather than hand signals to direct their dogs.

After recording hours of Jack's signals, I traveled to the Southern Arizona International Herding Dog Trial in Tucson, Arizona. Trials are timed competitions that test the ability of both dog and handler to work as a team at tasks similar to those necessary on the farm. I recorded the signals of fourteen teams and analyzed the results on a sonograph, noting the different durations, pitches, and amplitudes of sounds used by handlers.

Handlers have many commands to instruct their dogs, but all used four basic ones: "walk up," or move in a direct line toward the sheep; "down," or stop moving (either stand still or lie down); and two directional commands that instruct the dog to move to the right or the left around the flock of sheep.

Although handlers used a variety of whistles to send their dog left or right, they all used similar whistles to stop their dogs and to get them to walk up. The latter

Overleaf: *A Romanian gypsy and his horse*
Josef Koudelka; Magnum

Patrick Mommaerts

whistles were always given as at least two short, rapidly repeated notes, usually with an abrupt rise in pitch. Down whistles were usually given as one long note, either one that rose and then fell in pitch or one that continuously fell.

The use of similar whistles for commands is not surprising. After all, handlers learn from other handlers; some even buy trained dogs complete with cassette tapes of the whistles to which the animals are accustomed. But why would the two stop and start signals be so similar and directional signals so varied?

This question started me thinking about the many sounds that we make to our domestic animals that fit the start–stop pattern. Americans call cats with a series of short notes: "Here kittykittykitty," start horses with repeated clicks and smooches, and slow dogs and horses with a long, drawn out descending word like "stay" or "whoa." We use these signals to change an animal's rate of movement, just as the sheep dog handler's walk up and down whistles are given to stimulate or inhibit activity. The dog handler's directional signals, however, convey conceptual information and do not necessarily change a dog's rate of movement, which may explain why they vary. Perhaps we use similar types of sounds to both start and stop our animals because those sounds are more effective at getting the desired response. Some sounds might inherently stimulate or inhibit activity in mammals, and the animals themselves may have taught handlers to use the sounds best suited for a particular response.

I hypothesized that short, rapidly repeated notes stimulate motor activity in mammals and that long, single notes inhibit activity. The hypothesis led to several predictions that could be tested observationally and experimentally. If the type of sound used is driven by an animal's response, then animal handlers all over the world, independent of linguistic or cultural background, should use similar types of sounds to stimulate or to inhibit working domestic animals.

To test this prediction, I went to Texas to record Spanish-speaking race horse jockeys and livestock handlers on the Texas-Mexican border (where I butted heads with the uncooperative goat). The signals I recorded there fit my hypothesis perfectly, but given the close relationship between the Spanish and English languages, and numbers of handlers who did speak some English, the data did not sufficiently test the prediction.

To sample signals from many languages and cultures, I then recorded non-English-speaking animal handlers who were visiting the United States. Much of this work was done in Wyoming, where shepherds of several different language groups and cultural backgrounds—including many Basques from the mountains between France and Spain—work on ranches. I visited seven large sheep ranches to record the vocal signals used to control working sheep dogs and riding horses. One of these remote spreads was the Magnagna Brothers ranch outside of Rock Springs, Wyoming. The night I arrived with my husband and stepson (who acted as field assistants), we shared in a

A camel driver in Egypt, below, communicates with his working animal with much the same pattern of sounds used by a Basque shepherd in the American West with his dog and horse, right.

Wendy Shattil and Bob Rozinski; Oxford Scientific Films

dinner of lamb tail stew, traditionally eaten during docking season when the lambs' tails are removed to prevent later health problems.

In what was to become a regular routine that summer, the next morning I traveled with the docking crew to a shepherd's camp and recorded Basque- and Spanish-speaking horse and dog handlers during a break in their duties. At other ranches I was able to record Peruvian Quechua Indian, Navajo, Shoshone, and Arapaho handlers giving vocal signals to their working animals. The shepherds live in the modern equivalent of a Conestoga wagon, complete with tiny wood stove and sleeping platform. All the shepherds had at least one dog, and most had a horse to help them move the flock to better pasture.

Back at the university in Madison, I was able, over the course of several years, to record animal handlers speaking sixteen different languages, including Farsi to camels, Pakistani to water buffaloes, Polish to geese, as well as thousands of vocal signals in various tongues to dogs, horses, cats, and poultry. Although I was always careful in Wyoming and Texas to record handlers actually working with their animals, some of my Madison recordings were limited to interviews. I also traveled around the Midwest, recording English-speaking handlers of racing-sled dogs, protection and obedience dogs, and trotting, draft, dressage, and rodeo horses. Each signal was analyzed for the number of notes, the duration and band width of each note, and the initial and terminal frequency, or pitch.

Handlers of all these different backgrounds consistently used short, repeated, and broad-band sounds to activate their animals and longer, continuous notes to slow them. Horse handlers universally made clicking or "smooching" noises to start their horses, and dog handlers used hand claps, finger snaps, and short repeated words or whistles to call their dogs or to start them working sheep. Inhibiting signals were somewhat less consistent, but most were produced as a long, continuous verbal note, including a "huush" used by camel drivers and a long, drawn out "eeuuu" sound used by Chinese horse handlers. Speakers of each language appeared to have their traditional way of communicating with animals, but the sounds they used overwhelmingly fit the pattern I had recorded and analyzed in herding-dog systems.

Despite the many language groups I recorded, my data were not sufficient to show that these sounds are really more effective at eliciting a particular response. The universal use of certain sounds could simply be a species-specific tendency to use some sounds in different contexts. Short, rapidly repeated notes are common in many species of animals when an individual is excited. Producing the sound itself might change visual signals given off by the individual who makes it, which in turn influences an animal hearing it. Controlled laboratory studies were needed to determine if some sounds inherently stimulate or inhibit motor activity.

For these studies, research assistants and I raised twenty domestic dog pups in an indoor/outdoor kennel on the University of Wisconsin-Madison campus. The pups participated in a study that linked two different sounds to two different commands: come and sit/stay. Half the pups were taught to come to the trainer by a se ries of four short, rising tones ("fou short") and to sit/stay to one continuou descending tone ("one long"). The tone were generated by computer, with th same maximum and minimum frequen cies and total duration. (No tests were con ducted with four long signals, in order t control for total duration.) The other hal of the pups were trained on the opposit association of stimulus and response come to one long, and sit/stay to fou short. After ten days of training and test ing, each group was retrained on the oppo site association of stimulus and response For example, if a pup was initially trained to come to four short, it was then retrained to come to one long. This phase allowed us to compare each pup's response under the two conditions, an important procedure given the highly variable behavior of individual puppies.

The pups had to be raised without inadvertently learning to associate certain types of sounds with a positive or negative reinforcement, and the research had to be carefully controlled to eliminate the possibility of visual cuing. The simplest solution would have been to isolate the pups from human contact and acoustic stimuli. Since that would result in abnormal pups

that did not respond normally to humans or to unfamiliar sounds, the caretakers and trainers working with me restricted the sounds they used around the pups. Only a very quiet, low monotone voice was allowed; visual signals and leashes were also used to control the pups' behavior.

To prevent the pups from picking up inadvertent visual cues, all tests were made with the trainer and puppy facing in opposite directions. The results showed that the four short, repeated notes were indeed more effective at training puppies to approach a human. Pups trained to come to four short responded correctly more often than pups trained to come to one long. Moreover, all the pups originally trained to come to one long, and then retrained on four short, showed improvement. That was not true with the group originally taught to come to four short; when retrained to come to one long, few of them improved their scores.

We also recorded the number of forepaw steps of each pup for three seconds before and after giving the sound stimulus. Pups increased their motor activity after hearing four short and decreased activity after hearing one long.

One long note, however, was not more effective at teaching pups to sit and stay for three seconds. The results may reflect the complicated nature of that command; stopping and sitting down is itself an activity that requires the control of many muscle groups, while the subsequent "stay" part of the command then asks the dog to inhibit further movement. The data collected from the handlers indicated another factor at work: they divided "inhibiting" signals into at least two groups. Signals given to slow or calm an animal were produced as very long, relatively flat notes, while signals given to effect an immediate stop from a fast pace were usually one short, highly modulated note. Since I lumped the "slow" and "stop immediately" signals of herding-dog handlers together in one inhibiting category, the importance of these subcategories did not become clear until after I had finished the pup experiment and was able to analyze all the handlers' signals from the cross-cultural project.

But the difference between short, repeated notes and one continuous note was an important factor in whether an animal responded by increasing motor activity or decreasing it. That result was supported by electrophysiological studies conducted on the pups from the training study in collaboration with Dennis Molfese, of Southern Illinois University. Through painless electrodes glued to the pups' craniums (similar to an EEG test on a human), we recorded brain-wave responses to six different sounds, including the two training stimuli, before and after the initial training. In brief, the results showed that before training, the pups attended to the number of notes, as well as to the direction of pitch modulation. However, after training, once the stimuli were associated with increasing or decreasing motor activity, they preferentially attended to the number of notes.

All three research projects—the handler study, the pup training study, and the electrophysiological data—supported the hypothesis that different sounds have different effects on the mammal that hears them. But the question remains: why should some sounds be more effective than others at stimulating or inhibiting activity?

A growing body of literature in animal communication holds that in some species the production of short, repeated notes increases motor activity and approach toward the signaler. The mobbing calls of songbirds, characterized as short, repeated broad-band notes by ornithologist Peter Marler and co-workers, result in high activity levels and an approach from the

birds who hear them. Experienced bird watchers even use "smooches" and "squeaks" to induce elusive species to show themselves. Conversely, a long, narrow-band "hawk" call will cause other birds to freeze in place. Many animals, including dogs, sheep, horses, and songbirds, use short, repeated notes to call their young. House sparrows and herring gulls increase the rate of note repetition of their food calls—and thus attract other sparrows or gulls—only if the food available is in large or divisible quantities. Although each species uses its own characteristic sound (horses "nicker," sheep "gurgle," dogs "whine"), these signals all fit the pattern used by animal handlers to stimulate their working animals.

This response is not confined to nonhuman animals. Composers are well aware of the effect of many quick notes or of long, drawn out notes on their listeners, a response carefully exploited by those who write the musical scores for dramatic movies and TV shows. A delightful reference from the late 1800s describes playing "soft music" (funeral marches) and "jigs" to caged animals. The researcher reported that lions and tigers lay down to funeral marches and paced to jigs. Perhaps a biological basis exists for calling music the "universal language."

More recent research on newborn humans by psychologist Elliott M. Blass at Johns Hopkins University found that very young babies responded to "shush" sounds by quieting and staying still. Certainly, auctioneers are well aware of the opposite effect of rapidly repeated meaningless syllables on the excitement level of the crowd, just as a herding-dog trainer uses short repeated notes to excite a dog toward the sheep.

If mammals and birds tend to respond in similar ways to different sounds, we might eventually be able to translate the acoustic signals of animals, to improve our ability to communicate with them, and to understand a bit more about the evolution of human language. Maybe some day I'll know enough to go back to Texas and have a long talk with that goat. □

Fair day in Drumkeerin, County Leitrim, Ireland, brings farmers and flocks to town on foot. If a stop at the pub is in order, the herding dog can be relied upon to mind the sheep.
Jill Freeman

Sure-footed Bats

When there are fish to be had, these bats know how to put their best foot forward

Text by Anne Brooke

Photographs by J. Scott Altenbach

In the cool of an early Caribbean evening, a group of three bats, each with a two-foot wingspan, glided past me in a line and disappeared into the night over the bay. As I watched from a well-lit dock, the bats returned, speeding just inches above the water, and vanished again into the dark. Then I heard the splash of a small fish leaping out of the water. Seconds later, the line of bats reappeared. The first bat raked its feet over the water near where the fish had splashed; the bats following behind dipped their feet into the water at exactly the same spot. In my excitement at seeing them, I stepped forward for a better view and fell right off the dock into waist-deep water.

Several species of bats include fish in their diet, but only one has the reputation of being a fish specialist: the fishing bat, *Noctilio leporinus* (also called the greater bulldog bat because its drooping cheek pouches, pointed ears, and blunt nose give it a doglike appearance). Fishing bats range from Mexico to Argentina, close to lakes, rivers, or the sea. I study them on the small Caribbean island of Culebra.

Fishing bats have unusual physical characteristics that would seem of obvious help in the hunt: large feet, with long, talonlike claws to catch the fish, and long canine teeth to hold the slippery prey. But how the bats are able to detect fish in the first place remained a mystery until researchers using high-frequency sensors showed that the bats' echolocation calls were bouncing off fish fins sticking out of the water and even off the ripples created by a fish swimming just beneath the surface. The returning echolocation pulses enable the bats to determine a fish's speed and direction and thus where to strike.

As a fishing bat strikes, it raises i wings. Once the fish is impaled on i claws, the bat lowers its wings in a powe ful downstroke that lifts it up away fro the water. In a fraction of a second, swing of the feet transfers the squirmin fish into the mouth, where the bat's canin teeth easily pierce and hold it. With th fish secured, the bat chews it like a h dog, stuffing it headfirst into its two chee pouches, which can expand until they re semble small balloons tied beside the bat chin. Once the fish is safely tucked awa the bat can either finish the job of eating i flight or return to a perch to dine.

On Culebra, sheltered bays are home t enormous schools of sardines, silverside and needlefish. These small fish are mos vulnerable to predation just after sunse when larger fish, such as barracuda an jacks, chase them into the shallow wate near shore to feed on them. With few ave nues of escape left, the small fish attemp to flee by jumping into the air and soarin for a few feet before splashing back int the water. Small groups of fishing bats fl back and forth just along the water's edg seeking fish that have been driven to th surface. The bats must be within ten fee or so of a fish in order to detect it. When fish jumps, the nearest bat maneuver rapidly to the spot, with the others—per

haps eavesdropping on its echolocation calls—close behind.

During the past year I have made nightly collections of guano and partly eaten prey from beneath fishing bat roosts. After dissecting scats and carefully matching up fish scales, beetle and fly fragments, and moth scales to whole specimens, I have a good idea of what the bats eat. Throughout the year, their diet includes significant amounts of insects (which they catch directly with their mouths) and fish, but the relative proportions vary with the seasons. During the rainy season, the most common items in the guano are the remains of small flying insects; in the dry winter months, when insects are less abundant, the bats eat more fish. Fishing bats also spice up their diet with other, more terrestrial prey, using their feet to snatch up fiddler crabs as they wave their claws to attract mates on mud flats and to scoop up scorpions and crickets as they run across open ground.

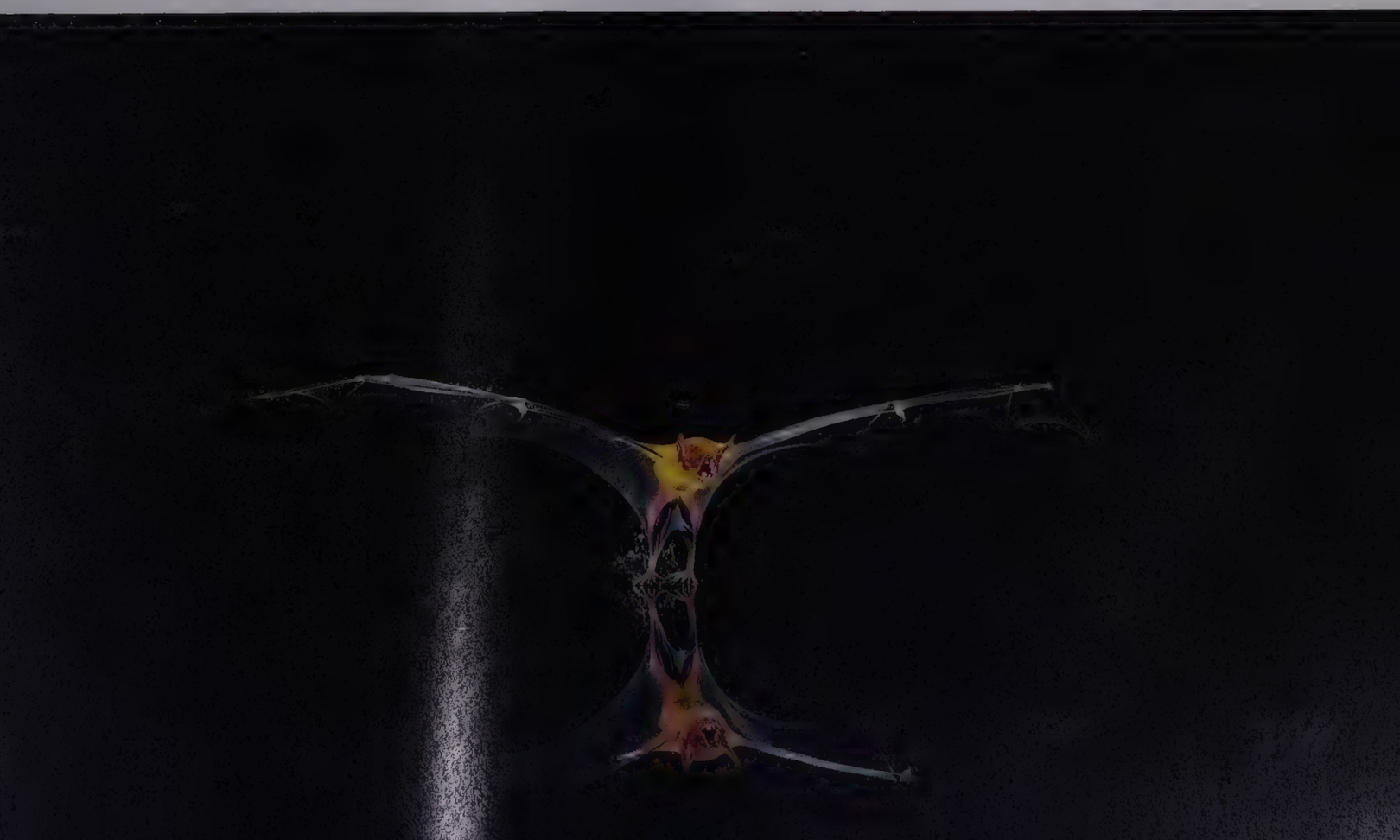
Piscivory, or fish eating, seems to have evolved independently in several bat families. As it turns out, size does not limit a species' ability to catch fish (although it may influence the size of fish any particular bat can catch). All the other species of bats that catch fish are smaller than the fishing bat. As for feet, some fish-eating bats have feet that are even larger, relative to body size, than the fishing bat's; others have relatively small feet.

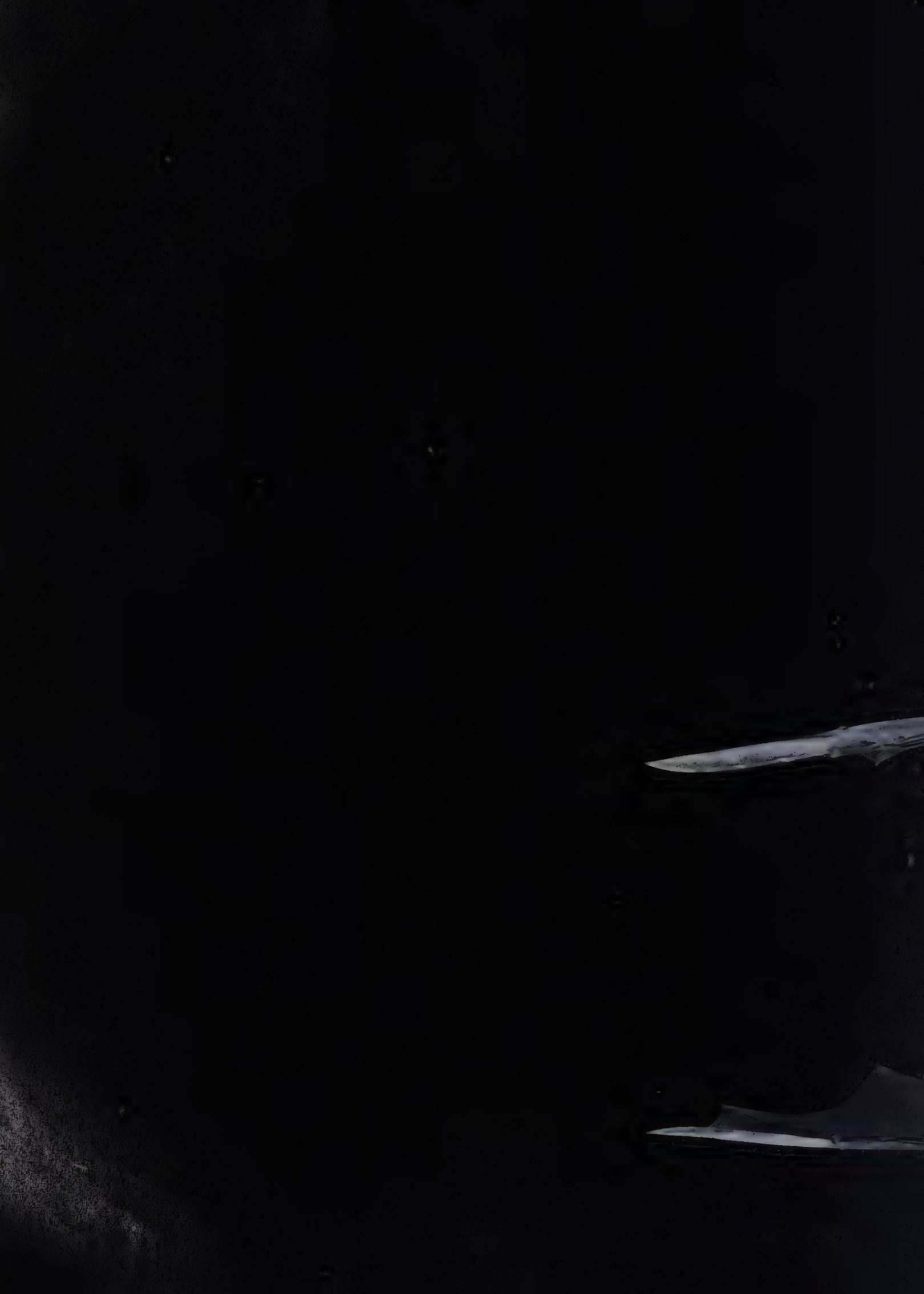
The greatest evolutionary modification may have been in how feet are used. Unlike hawks and owls, most bats do not use their feet to capture prey. Their slender legs and small feet are designed, not to bear weight, but to grasp a foothold in the roost, where the bats hang downward. Bats typically snap up flying insects in their mouths (which must be open for the animals to echolocate) or "field" them into their wing or tail membrane before sweeping them into their mouths. Even species with specialized foraging habits use their mouths: round-eared bats hover while plucking large insects off leaves, and frog-eating bats capture their prey by homing in on male frogs calling for a mate and then grabbing them in their strong jaws.

What, then, favored the evolution of fishing with the feet in some bats? Certainly being near water would be a prerequisite. Perhaps the ancestors of fish-eating bats hunted floating or swimming insects and then discovered that other food was available in the water as well. How the transition from eating insects to eating fish took place can never be known for certain, although a close look at the ecology and behavior of some of today's bats may help us one day have a better understanding of the origins of fishing bats.

There are currently five bat species that regularly trawl with their feet for fish, *Noctilio leporinus* being the largest. (Another four species occasionally catch fish, but we don't yet know how they go about it.) Twelve species are known to trawl for insects; whether any of these bats also catch fish has not yet been determined. Interestingly, *N. albiventris,* a Central American relative of the species I have been studying, is entirely insectivorous. Just why it does not fish has remained a mystery so far: although smaller than *N. leporinus,* it is larger, and has larger feet, than some of the other bats that do fish with their feet. I plan to keep asking questions about this and other species, but I also simply delight in watching *N. leporinus,* the bat with the impressive footwork. Now I just try not to fall into the water. □

Hunting for fish, a fishing bat flies low above the water, left. Once a fish is detected, the bat lowers its big feet for the strike, below. With a firm grasp on its catch, next page, the bat begins to transfer the fish into its mouth; it will then eat on the wing or on a shoreside perch.





Aripo Savannas, Trinidad

by Robert H. Mohlenbrock

The southernmost Caribbean island, Trinidad lies only seven miles from the coast of Venezuela. Geologists estimate it was still connected to South America as little as 6,000 years ago, and the island's plants and animals are more typical of the continent than of other West Indian islands. But Trinidad has been isolated long enough that as many as 10 percent of the 2,250 species of its plants are unique to the island.

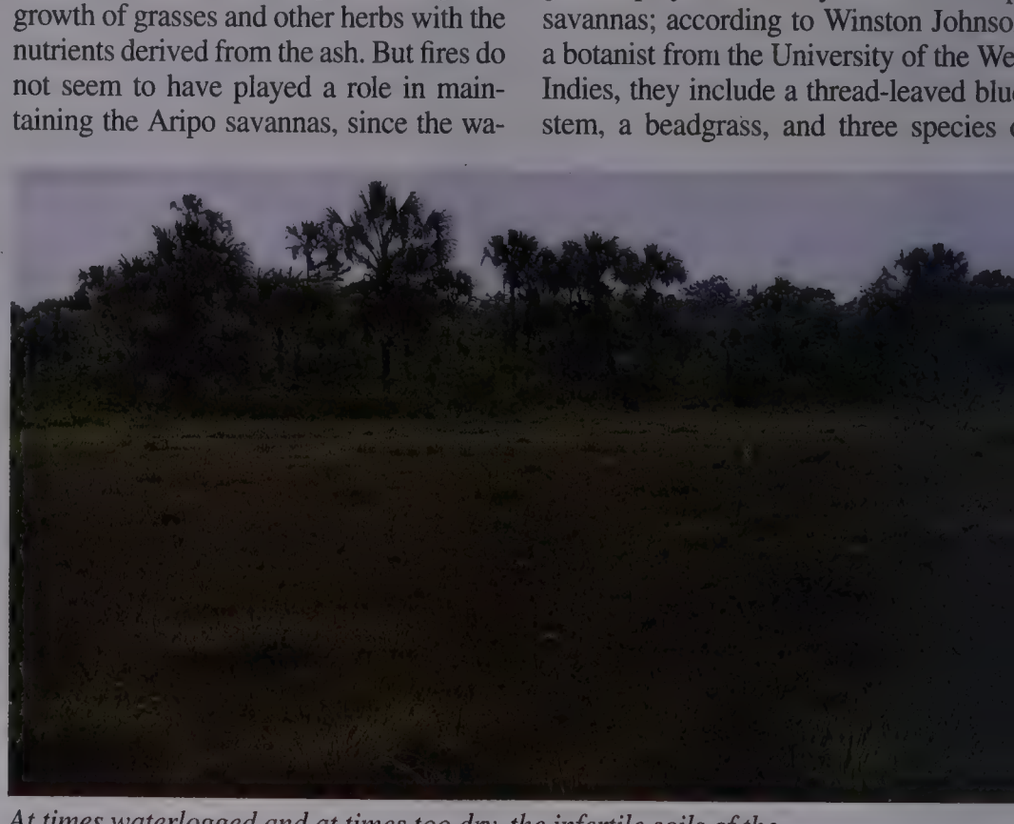
Trinidad is roughly rectangular, up to sixty-five miles north to south and fifty miles east to west, and contains three parallel mountain ranges. Along the south coast are the low Trinity Hills, presumably the "three hills" Columbus first saw in 1498 and for which, according to legend, he named the island (another legend has it that he gave thanks to the Holy Trinity for finally sighting land). The hills are partly cloaked in a seasonal evergreen forest, but most of the area has been tied up by large oil companies that have gated nearly all the access roads. Farther north are the Montserrat Hills, nearly 1,000 feet high. These are accessible but, as a result, have been subjected to timber cutting, farming, and settlement. The Northern Range, thought to be an extension of the Andes, includes 3,083-foot El Cerro del Aripo. It is covered with tropical rain forest, most of it impenetrable and unexplored.

South of the Northern Range are nearly flat alluvial terraces that are about 100 feet above sea level. Much of this zone is forested, occasionally by very wet forests known as marsh forests. The trees, which sometimes grow more than sixty feet tall, include white olivier (related to the rose family); a type of *Diospyros* related to the persimmon of the United States; and two moisture-loving palms, the moriche and the euterpe. Scattered among the forests, especially between the Aripo and Quare rivers, are nearly a dozen open areas, known as the Aripo savannas, where woody plants simply do not thrive.

The savannas, each only a few acres in size, have infertile, sandy soil underlain by an impermeable layer, or hardpan, of sandy soil cemented with iron oxides. During the rainy season, from May to December, the hardpan prevents the rapid percolation of rainwater, and the soil becomes waterlogged. As a result, plant roots are deprived of the oxygen they need for good growth. During the dry season, on the other hand, from January to April, the savannas receive inadequate rainfall. This combination of conditions appears sufficient to keep trees and shrubs from colonizing the savannas. In most regions of the world, fire is an essential part of savanna ecology, suppressing the growth of woody species while promoting the growth of grasses and other herbs with the nutrients derived from the ash. But fires do not seem to have played a role in maintaining the Aripo savannas, since the waterlogged soils deter the starting ar spreading of natural fires and lightni strikes are infrequent.

The savannas are not perfectly flat b contain small hummocks and depressior The hummocks develop partly as a resu of the presence of many termites ar earthworms, whose behavior modifies t soil. Botanist Paul Comeau has observe that the termites create a fine-texture upper soil layer free of stones and play a important role in breaking down dea plant tissues and releasing nutrients in the environment.

The dominant grasslike plant in the s vannas is actually a sedge, *Lagenocarpu guianensis*. This large, clump-formin species is able to tolerate the drastic se sonal fluctuations in moisture. A fe grasses play a secondary role in the Arip savannas; according to Winston Johnso a botanist from the University of the We Indies, they include a thread-leaved blu stem, a beadgrass, and three species



At times waterlogged and at times too dry, the infertile soils of the Aripo savannas, above, do not support the growth of trees. Right: Ginger grows on a trail leading to one savanna.

Photographs by Hans Boos

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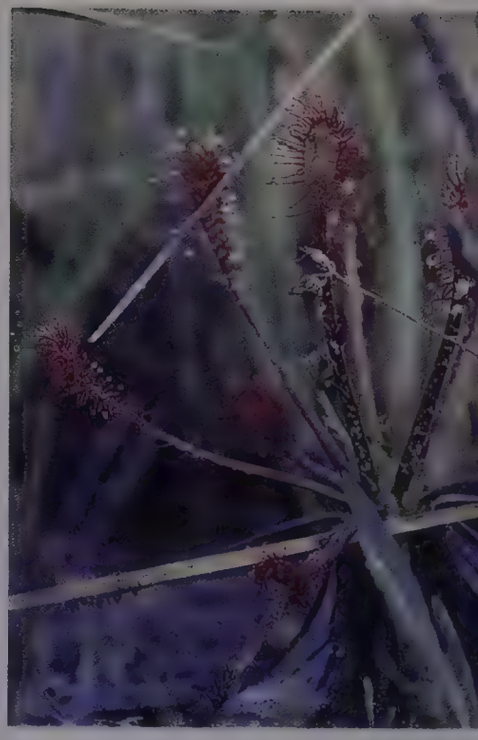
panic grasses. Other herbs include at least four species of beaked rushes. The savanna sedge, grasses, and rushes are mostly perennials that grow from underground rhizomes. Few annual flowering plants have been recorded here: they grow on bare ground between the clumps of grasses and sedge, where competition for survival is not as great.

Among the many small herbs in the savannas are two terrestrial orchids: one white flowered; the other red. Also conspicuous when in bloom are two species of yellow-eyed grass—not true grasses—whose solitary yellow flowering heads stand atop unbranched leafless stems. The larger of the two is the same species I have seen countless times on the Coastal Plain of the Carolinas. Spreading over some of the low-growing vegetation are the orange, stringy, leafless stems of *Cassytha,* the tropical parasitic flowering plant equivalent to the dodder found in temperate climates.

Carnivorous plants, which absorb nutrients from the insects they trap, are plentiful. Pink sundew, the same species that grows in the eastern United States, entangles insects in the sticky hairs that protrude from its leaves. In shallow depressions, which often contain standing wate as many as twelve species of bladderwor wait to capture tiny aquatic insects in a bladders attached to their roots.



Here and there in the savannas a small, isolated clumps of a broad-leave shrub with the unlikely name of fat por But the most conspicuous intrusions in th open savannas are occasional oasislik clusters of moriche palms, which grow u to thirty feet high in small pockets whe the soil texture allows better drainage. few shrubs also grow in these "palm i lands," often bedecked with air plants the bromeliad, or pineapple, family.

Between the open savannas and th marsh forest that surrounds them are tra sitional zones where the soil, moistur and oxygen conditions are too poor to su port the larger trees of the marsh forest b

Aripo Savannas

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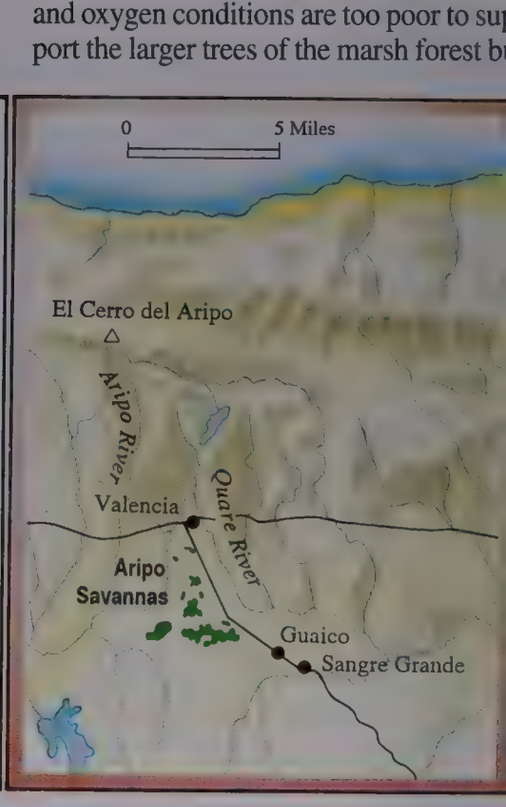
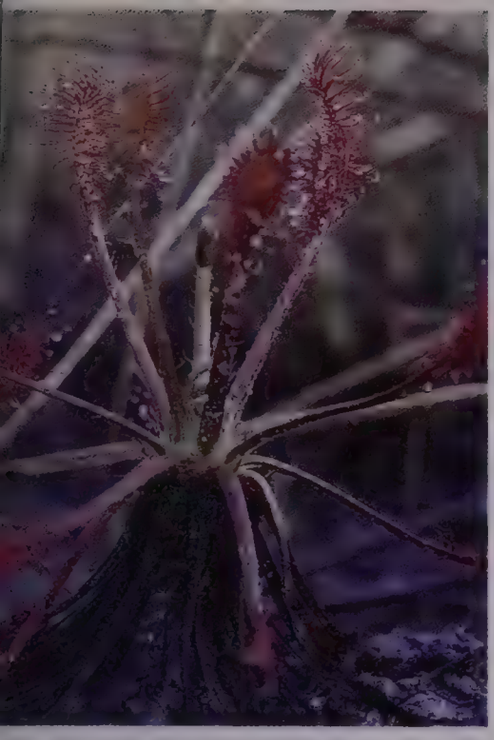


Joe LeMonnier



Pink sundew supplements its diet in the nutrient-poor savanna by using its sticky hairs to entrap insects.
Natura Productions

too rich to exclude a variety of other small trees and shrubs. The spiny bactris palm is an important member of the transition community, along with cuchape (related to the sea grape of peninsular Florida), wild ixora, wild calabash, and a species called wild mangrove (which is not a mangrove at all, even though its prop roots resemble those of the red mangrove). A giant sedge, whose sharp leaf edges inspired its common name—razor grass—grows nearly as tall as the shrubs.

The Aripo savannas are considered among the best savannas in the Caribbean, despite various disturbances that have threatened them. The United States built an air base in the area during World War II, while gravel mining is currently encroaching on the savanna borders. In addition, although natural fires apparently have not played a major role in the development of the Aripo savannas, recent fires presumably set by vandals have begun to alter the habitat. Susan Schwab, who has studied the effects of these fires, has noted which species seem to thrive following burning and which ones are harmed. Her findings suggest that if the fires continue, many rare plants may eventually disappear.

This month, Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, takes a departure from his usual beat, the 156 U.S. national forests.

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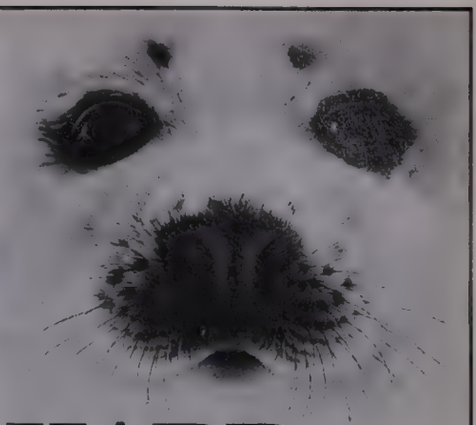

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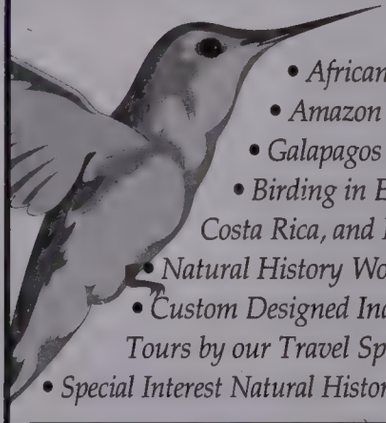

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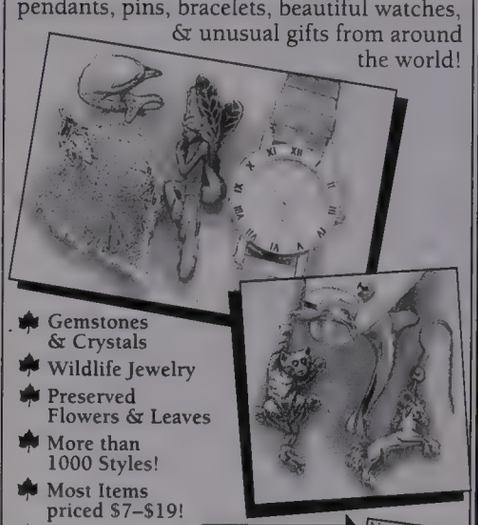

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America's First Food Writer

Columbus described the preparation of the cassava bread that is still baked in the Caribbean

by Raymond Sokolov

Here we are at last, celebrating the 500th anniversary of the landfall of Columbus. So the least a humble gastro-ethnographer can do is return to the scene of the first encounter between hemispheres, the Caribbean, and watch a modern native of the region cook her slightly updated version of the first recorded American recipe.

Columbus himself set down directions for the dish in the log of his first voyage just before and after Christmas in 1492. He had already made himself the first American economic botanist with his discussions of unfamiliar edible plants he happened upon. But by paying careful attention to a novel and locally important recipe on the island he named Hispaniola (on land now part of the Dominican Republic), he laid claim to the title of first American food writer. Here is what he wrote:

Sunday, Dec. 16, 1492: These fields are planted mostly with *ajes.* The Indians sow little shoots, from which small roots grow that look like carrots. They serve this as bread, by grating and kneading it, then baking it in the fire.

Dec. 26, 1492: The King [of Hispaniola] dined with me on the *Niña* and afterwards went ashore with me, where he paid me great honor. Later we had a meal with two or three kinds of *ajes,* served with shrimp, game and other foods they have, including their bread; which they call *cazabe.*

What we have here is a good, if terse, account of the making of cassava bread, the circular, flat specialty of markets in the Antilles even today. Although Columbus used *aje* to refer to almost any indigenous root or tuber, here he clearly meant the white, fleshy, underground portion of *Manihot esculenta* (known variously a manioc, cassava, and in Spanish, *yuca*).

Not to be confused (as it constantly is with the agave plant known to warm-climate U.S. gardeners as yucca, manioc is South American native spurge (from th Euphorbiaceae family) that prospers i slash-and-burn agriculture, as well as i more conventional fields, and which con tinues to be a staple in many cuisines o tropical America as well as Africa. It cam to Hispaniola with the South American In dians (known to ethnographers, with dif fering degrees of specificity, as Caribs Arawaks, and Taínos) who migrated nort and eventually succumbed almost entirel to the Spaniards and the new diseases they brought with them.

Some of these Amerinds have survived

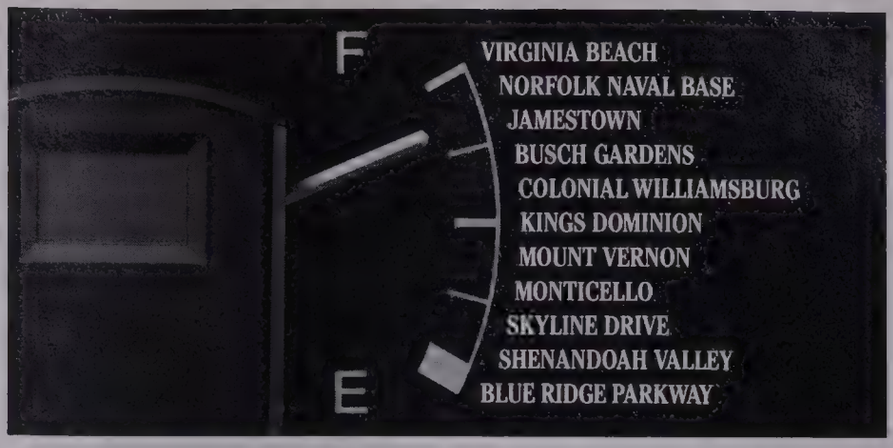
Beulah Riley pushes cassava roots through a motor-driven grater.
Lydia Pulsipher

There is an enclave on Dominica. But the most vivid legacy of their pre-Hispanic heyday is cassava bread, toasted in a wood fire, slightly chewy and long lasting.

Every week, Beulah Riley bakes many loaves for sale in the market near the port of Plymouth on the green volcanic island of Montserrat. Columbus first sighted Montserrat while sailing through the Leeward Islands on his second voyage in 1493. He named it after the mountain monastery near Barcelona where Ignatius Loyola was inspired to found the Jesuit order. But in the fullness of time, seventeenth-century Irish settlers made the island their own and began to exploit its potential for sugar with the help of Irish indentured workers.

Soon, African slaves took over the work (as well as the Irish names of their predecessors and owners). Today the majority of the 12,000 people on the island are black. By their choice, Montserrat remains a colony ("dependent territory") of Britain, and visitors get a shamrock stamped in their passports in green ink.

None of this takes away from the primeval authenticity of the basic method employed by Beulah Riley in her home in a hillside village called Long Ground. With her Amerindian physiognomy, Riley puts one in mind of a time long before airplanes or sugar or other European influences came across the sea. She is happy to ease her cassava-grating labors with an electric motor (which replaces the foot treadle of living memory, itself an improvement on the hand grating once normal all over tropical America in preconact villages), but the fundamental technique is what Columbus saw, and the bread she produces must be virtually the



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same as what the king of Hispaniola offered the future Admiral of the Ocean Sea.

Riley's house floats in a sea of green, chaotic to the naïve eye but as orderly as an Iowa farm once you learn to separate the banana plants from the dasheen (taro) and the red-stemmed stands of cassava. Nothing is accidental, least of all the processing of the cassava.

It stretches over two days. By the time I got there the first morning, two large plastic containers were filled with peeled cassavas soaking in water. Riley's son-in-law was brushing the roots until they were a uniform white. Riley herself was checking out the grating area, a wood table with a hand-punched metal grating disk connected by belts to an electric motor. When the machines were run by foot treadles, the same person would pump with his or her foot and also push root after root into the mean-looking, spinning grater. As the roots get worn shorter and shorter, the peril of pushing a finger into the grater increases.

Riley, her hair out of harm's way in many pigtails, wearing a sober Giorgio T-shirt and a jean skirt, protects her hands by grating two roots at a time, holding one in each hand. The roots are almost never the same size; so when one gets too small to hold safely, she pushes it into the blade with the longer root. And so it goes, root after root: white, mushy grated cassava spins off the blade and falls through an opening in the table to be collected underneath. Riley leans into a shoulder-high vertical board nailed to the end of the table. It not only braces her but it also catches the splash of grated cassava that the blade sometimes sends back at her.

The work is slow and steady. An evangelical radio station plays in the background. One of Riley's daughters looks after a new baby (another daughter studying in Texas). But eventually, th son-in-law has the whole batch trussed u in a large, strong, but porous plastic ba lined with a flour sack.

Milky liquid starts pouring out immed ately as he tightens the ropes around th bag. This is the toxic juice of the cassav high in hydrocyanic (a.k.a. prussic) aci an aqueous solution of hydrogen cyanid HCN. To get rid of it, the son-in-law se the cassava bag in a tongue-in-groov press whose handle fits into a notch cut i a tree. Then he weights the press wit large stones and leaves them there, whil white liquid pours out the grooves in th press, until evening. If he leaves the ca sava in the press any longer, he says, it ge too dry for baking.

But what about the residual cyanide Why isn't it toxic? And isn't there a trad tional Guyanese condiment called cassa reep made from the supposedly poisonou juice pouring out of that bag in the press The North American observer is also cur ous as to why the cassava he buys in Ne York markets doesn't kill him. Are thes the so-called sweet cassavas that aren poisonous? Or is the heat of cooking wha neutralizes the prussic acid?

Even in manioc-consuming areas, naïv questions like these come up constantly i conversation, even though the scientifi facts are well established and show hov safe a plant cassava is under almost a likely circumstances.

Cassava becomes toxic only when th outer covering is cut. Then small sac exude a milky latex containing manihc toxine, a cyanogenetic glucoside tha breaks down into prussic acid, glucose and acetone. No doubt this whole proces evolved as a defense against animal an insect attacks. The human animal discov ered, however, that he could promote th elimination of the poison and thereby pu rify cassava by soaking it in water, by cut ting it up into small pieces, or by mil heating. All these methods promote th contact of a naturally occurring enzym called linase with the acid. Linase liberate the acid into the air.

The original cassava farmers discov ered how to exploit this biochemical proc ess without understanding how it worked They also noticed that some varieties o manioc were not toxic, and they assumed as did botanists until quite recently, tha the "sweet" varieties resulted from som genetic difference. It turns out that the en vironment is the decisive factor. Clones o poisonous plants will grow up sweet i

Two West Indian cassava recipes adapted from Winifred Grey's *Caribbean Cookery,* Collins, London, 1965

Cassava Pone

2 cassava (manioc or yuca*) tubers*
1 coconut
½ cup sugar
¼ teaspoon freshly grated or ground nutmeg
½ teaspoon cinnamon
½ cup currants
2 tablespoons shortening

1. Preheat oven to 350 degrees.
2. Peel, wash, and grate the cassava. Grate the coconut meat.
3. Mix all ingredients with enough water to make a stiff dough.
4. Spread in a well-greased shallow baking dish and bake until brown, about 1½ hours.

Yield: 4 to 6 servings

Cassava Bread

4 cups finely grated cassava
2 teaspoons salt

1. Mix the salt and the cassava. Taking one cupful at a time, place the meal in a strong cloth and wring out all the juices. Crumble the meal and rub it through a fine sieve.
2. Put a baking stone or iron on an evenly glowing fire and sprinkle a little cassava meal on it. When the meal browns, the stone is hot enough. Brush off the meal and place tin rings on the stone. Spread a thin layer of meal in each ring. As soon as the steam rises, shake and remove the ring.
3. When the bread is firm enough, turn with a knife. Turn frequently until dry and stiff. Do not touch the bread with the hands but remove from the stone with a knife and stand on edge. It can be stored in a tin. Before serving, toast and butter or spread with melted butter and brown lightly in a quick oven.

Yield: 2 to 6 rounds depending on size of rings

Cazabe Tostado con Mantequilla y Queso Parmesano

Venezuelan cassava bread toasted with butter and Parmesan cheese

(Adapted from Armando Scannone's *Mi Cocina a la Manera de Caracas,* Edicion Bolsillo, Caracas, 1986)

Cassava bread
Butter
Finely grated Parmesan cheese

1. Preheat the oven to 350 degrees.
2. Cut the cassava bread in small pieces. Spread them on one side with butter. Then dredge the buttered sides in the grated cheese.
3. Set the prepared slices cheese side up on a baking sheet and bake for about 10 minutes or until the cheese melts and turns golden brown.
4. Remove from the oven and serve immediately.

ew settings and vice versa. My assumption is that the cassava in supermarkets is nontoxic, but I am unwilling to test this proposition by gnawing on a raw root.

In any case, the primordial technique that Beulah Riley and her family use in preparing cassava meal incorporates two of the methods science endorses for purging the root: laborious soaking and thorough chopping. The prolonged pressing and draining of juice offers still a third exit route for residual poison and linased acid.

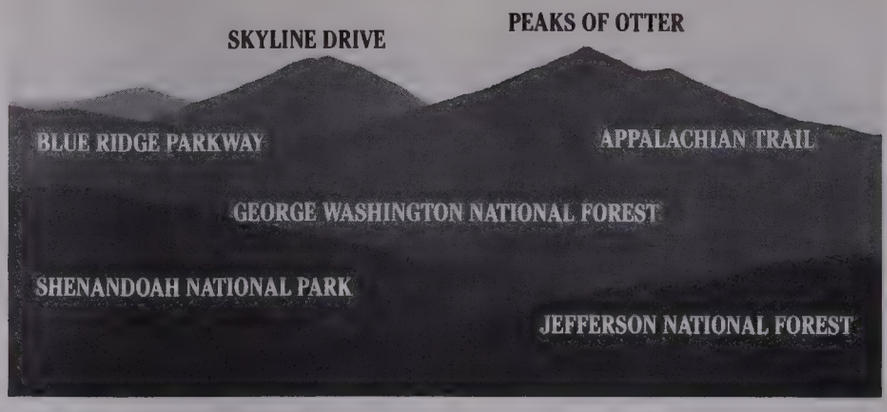
Finally, on the morning of the second day, Riley's son-in-law sifts the pressed meal through a galvanized metal circular sieve shaped like a French tamis but created by punching holes in the metal with a nail. What's left in the sieve—root fragments that didn't get finely grated—is fed to the pigs. It's called musha, and after it has dried, it traditionally has been the base of various country dishes, including Barbadian jug jug. Teen-age girls say to each other, "Who has musha in sun, looks for rain." They mean that a girl who has something valuable out in the open (especially a boyfriend or fiancé) must be wary (of competition from other girls).

Meanwhile, Riley is tending a fire of smallish branches, mostly driftwood. She fans the fire with a spray of mango leaves pulled from a tree, heavy with red-blushing fruit, behind the house. Her griddle is a rectangular piece of sheet metal scavenged from a construction site. She sets two metal rings on the griddle. They are about sixteen inches in diameter and a couple of inches high. Inside these rings she spreads a thin layer of salted cassava meal and smooths out the top of the "loaves" with a flat wooden baker's peel (the underside will keep its original coarse texture).

The meal is barely a quarter inch thick, and when it solidifies (the rings have been removed), Riley deftly flips over the whole loaf and cooks it a bit longer, so that both sides are brown. She then folds the bread in half (while it remains on the griddle), and when she thinks it has cooked through sufficiently, she sets it to one side where a stack will soon collect.

Cassava meal has many other uses besides bread—as porridge, in dumplings, in chicken stuffing, as filler for blood sausage. But the bread is the link with the distant past: the past into which Columbus brought the future 500 years ago.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.



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CONTACT: CULTURAL CHANGE, ALTERNATE PERSPECTIVES

In conjunction with the quincentennial celebration of Columbus's arrival in the New World, the Museum's Education Department will be exploring the changes and new developments that occurred among indigenous and non-European cultures after European contact.

Among the scheduled programs are a talk by musician-folklorist Tchin, "Christopher Columbus: Dispelling the Myth, 500 Years of Resistance and Survival of Native Peoples," on Tuesday, October 6; a dance-drama about the 1791 revolution that established Haiti as the first free black republic in the New World, presented by the Children of Dahomey on Saturday, October 17; Andean music and its Spanish themes, demonstrated by Pepe Santana, Rothman Teran, and Paco Moreno of Inkhay on Saturday and Sunday, October 3 and 4; a participatory performance of African American musical traditions rooted in the Gullah experience, by David Pleasant and Company, on Saturday and Sunday, October 24 and 25.

For a schedule of events, call (212) 769-5315. These programs are free and made possible in part by gifts from the Vidda Foundation, the Samuel and May Rudin Foundation, and the family of Frederick H. Leonhardt.

FILM FESTIVALS

Presentations from the 1992 Margaret Mead Film and Video Festival continue through Sunday, October 4, with *2000 Years of Freedom and Honor: The Cochin Jews of India* and *Marriage Egyptian Style*. At a benefit event on Friday, October 2, the audience will meet with film and video makers and view Jean Rouch's film *Margaret Mead: A Portrait by a Friend,* as well as his work in progress on Margaret Mead. Benefit tickets are $30 ($27 for members). An advance package ticket for three weekday evenings and two weekend days of screenings is $40 ($36 for members). Daily tickets are $10 ($9 for members).

An international film series on environmental themes related to climate change and cultural attitudes will be shown on Sunday, October 18, from noon until 5:00 P.M. These films are free with Museum admission.

For a complete schedule of film Events, call (212) 769-5305.

FALL LECTURE SERIES

Issues of public interest raised by the exhibition "Global Warming: Understanding the Forecast" will be addressed in a four-part program beginning Monday, October 19, with a talk by Michael Novacek, Museum curator and dean of science. On Monday, October 26, Michael Oppenheimer, senior scientist for the Environmental Defense Fund, will discuss climate change. The series continues for the first two Mondays in November.

Drawing on themes from her new book, *Anatomy of Love: The Evolution of Monogamy, Adultery, and Divorce,* anthropologist Helen Fisher will examine brain and behavioral differences between men and women in two Tuesday-evening lectures, October 20 and 27.

Charles J. Cole, curator in the Department of Herpetology, will present two Monday-night lectures, October 19 and 26, on the reproduction, genetics, ecology, and evolution of unisexual lizards and their bisexual relatives.

On Thursday, October 22, *Natural History* senior editor Richard Milner will give a slide-illustrated talk, "Charles Darwin and the Victorian Spiritualists," about an acrimonious court battle between scientists and psychics during the great naturalist's secret crusade against supernaturalism.

Beginning October 22, Sidney S. Horenstein, coordinator of the Museum's environmental public programs, will give four Thursday-evening talks on overlapping issues in geology and the environment in metropolitan New York.

Environmental history and new art genres will be the subject of talks on Tuesday, October 20 and 27, by Barbara C. Matilsky, curator of "Fragile Ecologies: Artists' Interpretations and Solutions," an exhibition at the Queens Museum of Art.

William Schiller, lecturer in botany at the Museum, will explore the role of coastal plants along the Atlantic seaboard in a four-part series, on Monday afternoons from 2:30 to 4:00 P.M. starting October 19, or Thursday evenings from 7:00 to 8:30 P.M. starting October 22.

For times, ticket prices, and other information, call (212) 769-5310.

FALL WORKSHOPS AND FIELD TRIPS

A climate-modeling workshop, led by Stuart R. Gaffin, research scientist for the Environmental Defense Fund's Climatic Change Program, will be held on Saturday, October 24. This program exploring the parameters and assumptions behind the global warming forecast is recommended for adults with some science background and will include a trip to the NASA Goddard Institute of Space Studies.

William Schiller, the Museum's lecturer in botany, will lead three two-hour expeditions in Central Park to observe season changes and discuss plant identification an ecology. The trips are scheduled f Wednesday, October 14, and Saturday, O tober 17. For more detailed informatio call (212) 769-5310.

THE SEPHARDIC DIASPORA

An exhibition at Yeshiva University M seum, "The Sephardic Journey: 149 1992," portrays the breadth and diversity the Diaspora after the Jews were expell from Spain. On Thursday, October 2 Gabriel Goldstein, an assistant curator Yeshiva University Museum and a memb of the international team that developed t exhibition, will trace the flowering of hu dreds of Jewish communities from the Mi dle East and North Africa to Europe and t New World. This lecture takes place at 7:0 P.M. in the Main Auditorium. Tickets a $10 ($7 for members). Call (212) 769-560 for ticket availability.

NIGHTWALKERS

Storyteller Laura Simms returns to t Museum on Friday, October 30, in t Kaufmann Theater to tell ghost stories fro around the world. The Halloween progra for children (ages five through twelve) b gins at 6:00 P.M. and includes "The Bi Bird," "Witch," "Skeleton Woman," an other tales of witchcraft, magic, and wan dering spirits. "Abu Sultan's Tongue," story from Basra, and "Bear," a shamani Inuit tale, will be among those presented t the adults, beginning at 8:00 P.M. Children tickets are $8 ($4 for members); adult's tick ets are $12 ($8 for members). Call (21 769-5606 for ticket availability.

EARLY SKY WATCHERS OF NORTH AMERICA

On Monday, October 5, Edwin C. Krup director of the Griffith Observatory in Lo Angeles, will talk about the traditional as tronomy and skylore of Native American This lecture, at 7:30 P.M. in the Planeta ium's Sky Theater, is the second in a two part series: "Astronomy in the America Before Columbus." Tickets are $8 ($6 fo members). For more information abou Planetarium events, call (212) 769-5900.

These events take place at the America Museum of Natural History, located o Central Park West at 79th Street in Ne York City. The Kaufmann Theater is locate in the Charles A. Dana Education Wing The Museum has a pay-what-you-wish ad mission policy. For more information abou the Museum, call (212) 769-5100.

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Halfway to Winter

by Gail S. Cleere

Halloween, once the eve of the pagan fall festival of Samhain, is celebrated on the last day of the month. In olden times it marked when the sun was midway between the autumnal equinox and the winter solstice. Samhain was a particularly auspicious day for the ancient Celts—the start of their winter season and the only day of the year when the dead could revisit the living. On this night in ancient Ireland, a new and sacred fire was kindled, from which all the fires of Ireland would be lit. This tradition, which was believed to ward off evil spirits, is retained in our country bonfires and front porch jack-o'-lanterns. That name itself comes from the old Irish tale that tells of a stingy man named Jack, who, barred from Heaven for his penuriousness and barred from Hell for his practical jokes on the Devil, was condemned to walk the earth with his lantern until Judgment Day.

In the Middle Ages, the church attempted to root out the paganism associated with the Samhain festival by naming November 1 All Saints' Day (Allhallows), and November 2 All Souls' Day. Mumming (actors performing in disguises) was popular, and the poor went begging for "sweet soul cakes," which would be given as payment for prayers they promised to say for the dead. They chanted: "Soul, Soul, for a souling cake, I pray, good missus, a souling cake. Apple or pear or plum or cherry, Anything good to make us merry." The alternative, one supposes, would make them mad. This may be the origin of the current trick or treat, along with the costuming and general mischievousness. One might also note that the prayers have been forgotten altogether, not to mention the astronomy.

THE PLANETS IN OCTOBER

Mercury is difficult to spot this month if your horizon is obstructed. In the latter part of the month, look for the planet low in the west in early evening. The path the planet traces through the sky is at present at a very low angle to the horizon. On the evening of the 27th, the planet can be found just below and to the right of the thin crescent of the two-day-old moon.

Venus finally emerges from the solar glare, gleaming brilliantly at -4.0 magnitude, low in the southwest after sundown. On the 27th, look for Venus just above the red star Antares in the heart of Scorpio. On the 28th, you'll find Venus near the three-day-old crescent moon, which will be to the left of the planet, the two of them forming a stunning sight.

Mars rises in the late evening, easily found high above the left shoulder of the great constellation Orion, not far from the twin stars Castor and Pollux in Gemini. By morning, this threesome is high in the southern sky. Look for Homer's "blood-stained, murderous god of war" just 3° north of the waning gibbous moon on the 18th.

Jupiter emerges from the morning twilight glow and can be seen low in the east before sunrise. This gas giant is now found between Regulus in Leo and Spica in Virgo, closer to the latter star.

Saturn, a showpiece in early evening skies as a lone luminary in the southern sky after sunset, sets just after midnight. Found amid the fainter stars of the constellation Capricornus, Saturn remains the brightest object in a somewhat subdued area of midevening constellations.

Uranus and **Neptune** remain in Sagittarius, gradually leaving the evening scene as they move toward the evening twilight glow along with the rest of the summertime stars. With binoculars or a small telescope, look for them low in the southwest at sundown. Consult a star map in one of the popular astronomy magazines for the exact positions of these distant planets. On the 3d the moon passes above these tw blue-green worlds.

The Orionid meteor shower occurs o the night of the 21st. This is usually th third most reliable shower of the yea after the Perseids of August and the Gem inids of December. The Orionids can ave age anywhere from ten to seventy meteo an hour. As is the case with all meteor what we are seeing is the debris left behin in the path of a comet, a small amount o which encounters the earth and burns up i its atmosphere (in this case the debri comes from Halley's comet). The meteo will be seen best in the hours just befor moonrise all over the sky, although the ra diant, the point where they appear to orig inate, is located in the constellation Orio This is predicted to be a particularly goo year for the Orionid meteors.

The **Moon** reaches first quarter on th 3d at 10:12 A.M., EDT; full moon is on th 11th at 2:03 P.M., EDT; last-quarter moo is on the 19th at 12:12 A.M., EDT; and nev moon is on the 25th at 3:34 P.M., EST.

October's full moon is traditionall called the hunter's moon. It follows th harvest moon (which occurs either in lat September or in early October and is th full moon closest to the autumna equinox). For a few days before and afte these two full moons occur, moonris tends to be earlier in the evening than i usually is at this phase. People wh worked the land in earlier times were thu able to continue their harvesting and hunt ing past sunset to lay in their provisions fo a long winter.

Note: Daylight saving time ends at 2:0 A.M. October 25. Set clocks back one hour

Gail S. Cleere writes on popular astron omy and is a founding member of the International Dark Sky Association, an organization dedicated to preserving the skies for astronomy.

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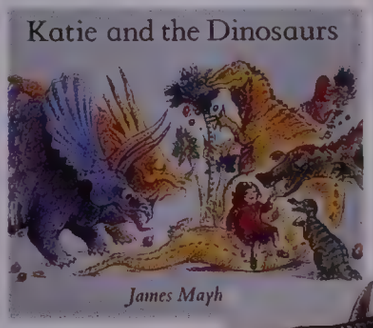

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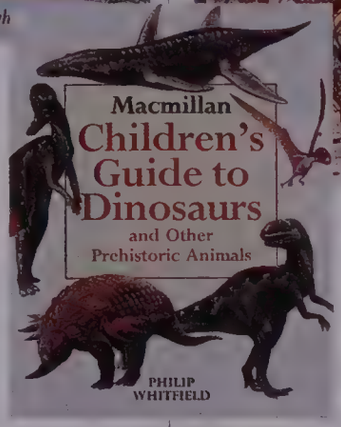

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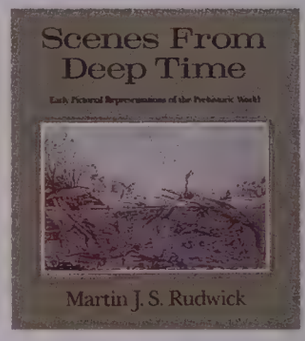

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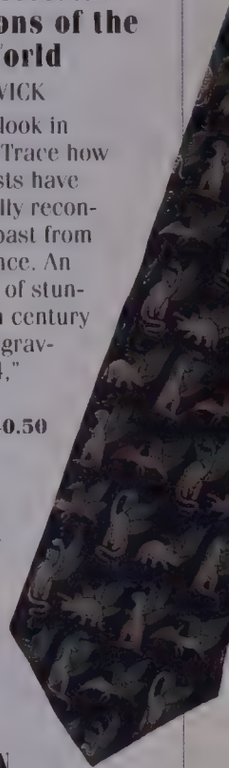

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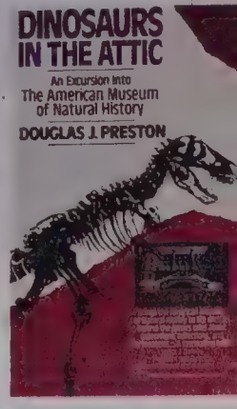

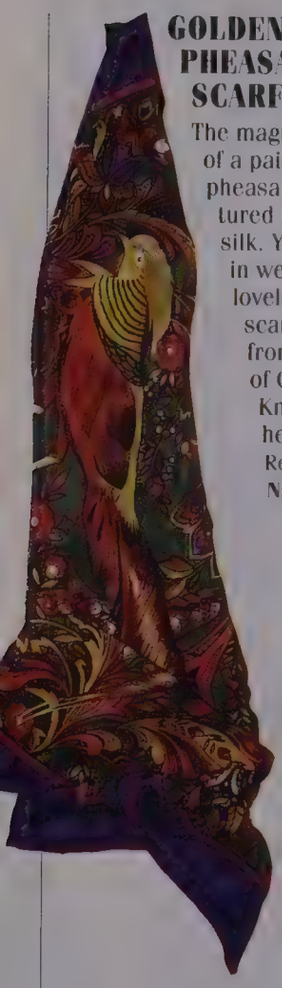

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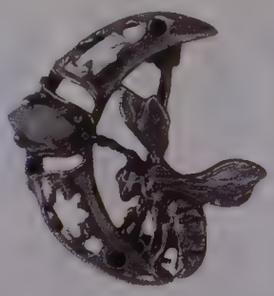

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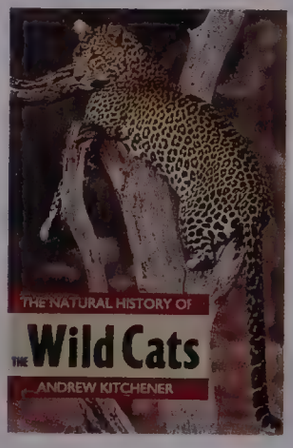

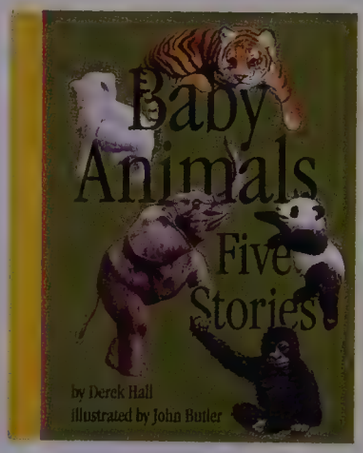

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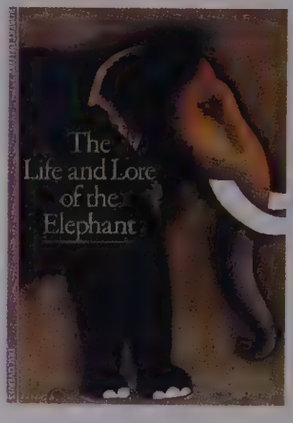

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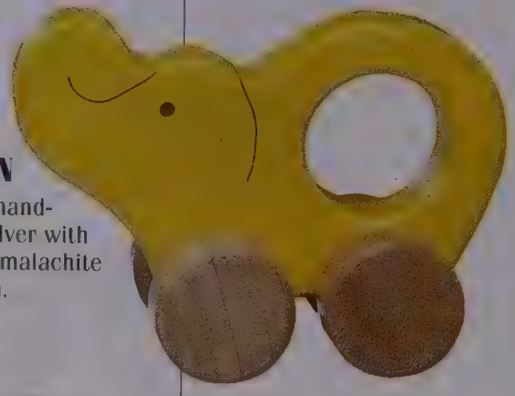

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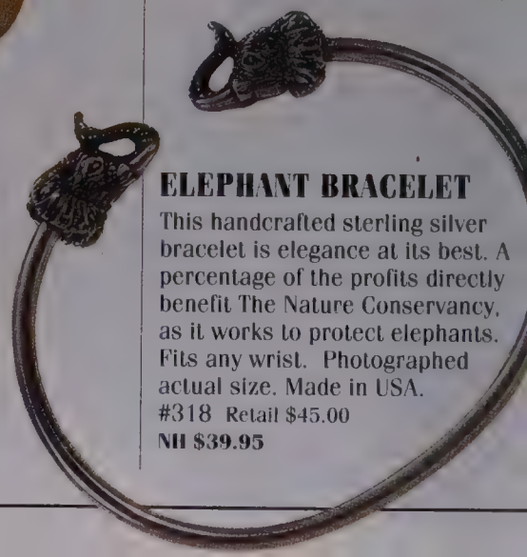

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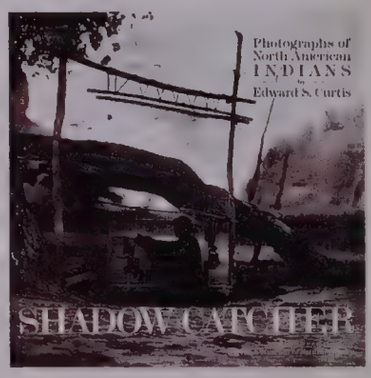

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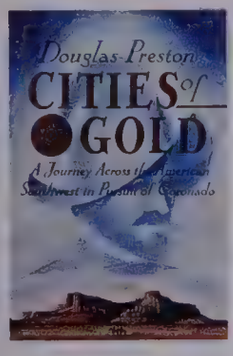

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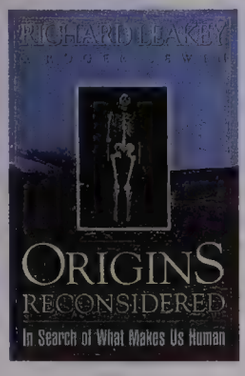

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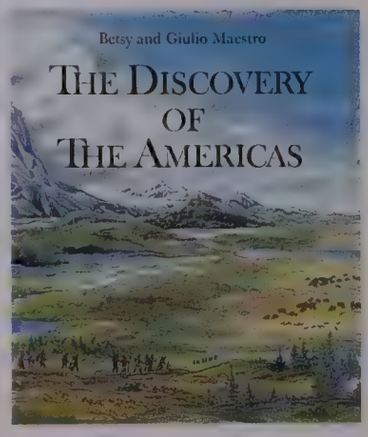

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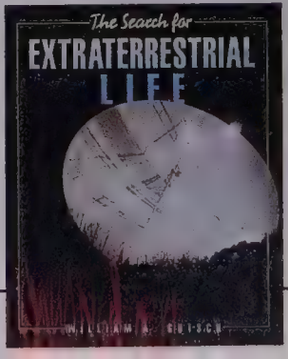

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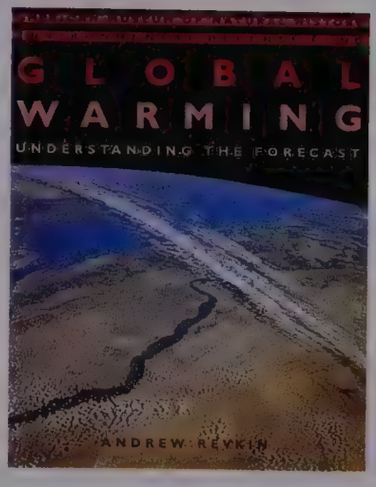

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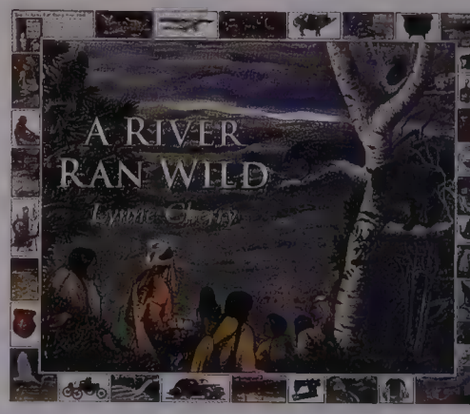
LYNNE CHERRY



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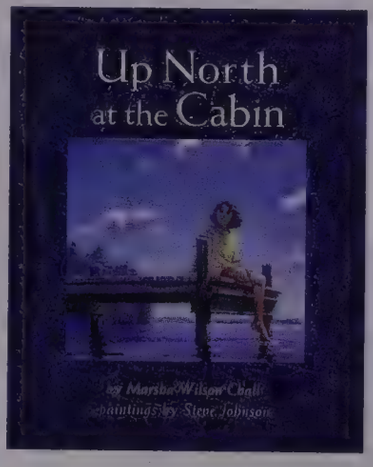

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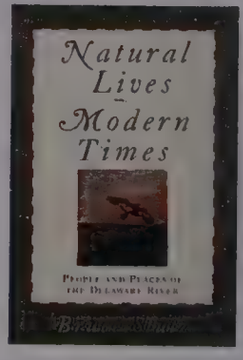

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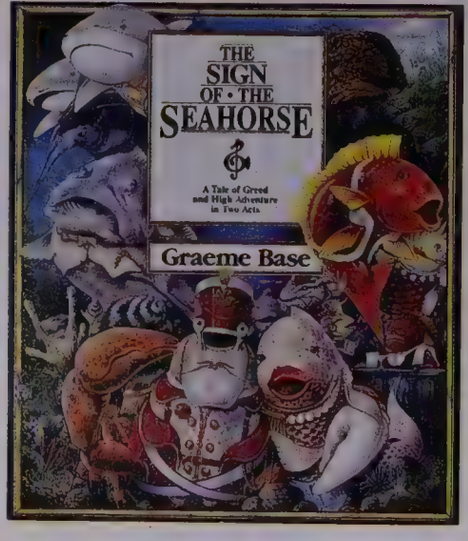

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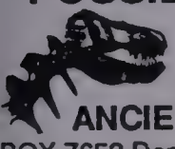

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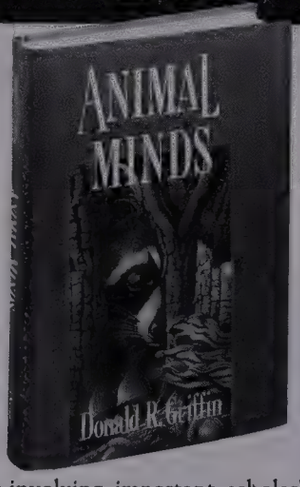

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The Innocent Science

by Joseph Kastner

The Botanizers is an uncommon natural history book. It has very little to do with sepals and calyxes and the expected stuff of botany and a great deal to say about self-improvement, natural theology, and the fabric of American culture in the nineteenth century. In taking up what was called the innocent science, Elizabeth B. Keeney shows us how the urge to know nature is woven into that fabric.

Botanizers were the amateurs of botany, as distinguished from botanists, who were the professionals—pretty much as birders today are distinguished from ornithologists. In the nineteenth century, which is the period Keeney covers, hundreds of thousands of Americans occupied their spare time by finding plants, identifying and classifying them, and preserving them between sheets of delicate paper. But their interest in this discipline—taxonomy—was secondary. They were more committed to self-advancement, Keeney emphasizes, than to the advancement of science.

THE BOTANIZERS: AMATEUR SCIENTISTS IN NINETEENTH-CENTURY AMERICA, by Elizabeth B. Keeney, *The University of North Carolina Press, $34.95; 195 pp., illus.*

Keeney keeps her eye on the moral and social impulses that motivated the botanizers, finding her sources not so much in manuals and learned journals as in *Godey's Lady's Book, The Youth's Companion,* and the novels of Louisa May Alcott. Her points are bracketed by two nineteenth-century quotations assessing the virtues of botanizing. "Botanizing," said one proponent, "accustoms the mind to systematic arrangement, definite rules of classification, and strict attention to the importance of terms." Moralists, holding that "the natural tendencies of botany are altogether good," saw it as "the best corrective of the heartless and demoralizing state of society."

It all began with Carl Linnaeus, who had brought order out of the chaos of botany by devising the first workable system of identifying and classifying plants. Based on the number of pistils and stamens in flowers, the system was straightforward and consistent—and also superficial and relatively short-lived. Still, its impact on the intellectual life of the Western world was enormous, because almost anybody with will and patience could master the identification and classification of plants. Botany became the most accessible of sciences and, in an unprecedented way, opened science itself to the untrained. Generations of "virtuosi," educated and mostly upper-class men, formed an intellectual elite known as the natural history circle, the most cohesive scientific group of the Enlightenment.

American botanizers were more plebeian, as befitted their new democracy. Some, having mastered the rules of taxonomy, reached professional levels. But most worked along the fringes of the discipline, settling for the rudiments and concerned largely with building up collections of plants.

Not everybody could botanize. One had to be literate enough to understand the manuals and prosperous enough to have the time. It was a middle-class activity, reflecting in its earnestness the Protestant work ethic, the Calvinist insistence on seeking worthy ways and egalitarian demands for self-betterment—to take advantage, it was said, of "the improving hand of culture." "In an age buzzing with reform," says Keeney, "the image of botany as an improving activity served firmly to establish its popularity. Self-improvement was an inexpensive and available means of at-

taining social and economic advancement by exercising each individual's obligation to cultivate God-given abilities to his or her fullest potential."

This led to another virtue. Botanizing was, to a contemporary, "so pure, so refined, and so unalloyed by human passions" that it stood as "the most genteel and delicate" of sciences. It did not involve handling dead animals, which zoologists had to do, or shooting birds, as ornithologists then did. "To middle-class moralists," Keeney remarks dryly, "gentility was a compelling call to botanize."

Women were especially keen botanizers, as they were normally excluded from the manly outdoor activities of hunting and fishing. Female seminaries took the lead in teaching botany, although, Keeney points out, "pedagogy and morality" got more attention than science. Women filled the audiences at natural history lectures, especially those given by the enormously popular Amos Eaton, who had learned botany in jail (after having been unjustly charged with forgery), and who went on to write and sponsor botanical guides, including the 1817 best seller *Manual of Botany for the Northern States*. One of his pupils, Almira Hart Lincoln Phelps, was the most influential of the female botanizers and the author of *Botany for Beginners*, which went into more than forty editions and printings.

Thus instructed and inspired, women all but took over the genteel science. Doctors, who worried about the sedentary lives well-bred young ladies led, prescribed botanizing's long walks and fresh air as "conducive to health and cheerfulness." Women organized their own botanizing clubs and formed a widespread floral sisterhood through correspondence and swapping plants and solutions to problems. One persistent problem was their

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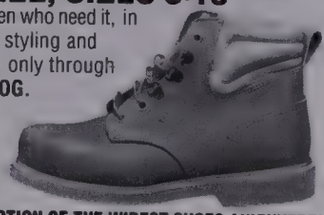
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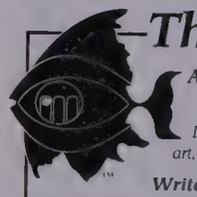
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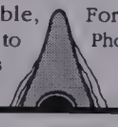
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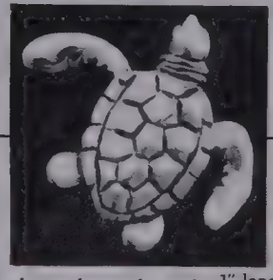
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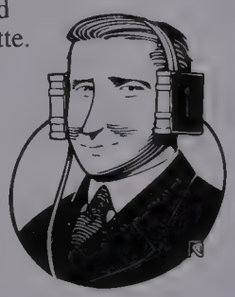

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clothing. Long skirts caught on briars, and tight dresses hampered action. Only a bold few adopted Amelia Bloomer's radical pantaloons.

The effeminization of botany presented problems for young men. While their teachers told them that botanizing was ideal for the "able-bodied and vigorous minded," their peers jeered at their taking up girls' work. The more susceptible were lured into helping females who had been advised to flatter young men so that they "will scale rocks and jump from bog to bog to secure plants for you," thus turning the effeminate activity into an act of chivalry. At Antioch College, certain botanizing days were restricted to female students, other days for males. On some days, however, the bars were let down so that both sexes could go plant hunting—and these may have been the best-attended botanizing sessions..

For many, botanizing had a religious cast expressed in what was called natural theology, which taught that a better understanding of God and his work could be reached through understanding the workings of natural law. "Delicate wildflowers," said one sermonizer, "seem to whisper a lesson of love for Him who has manifested His goodness by placing forms of beauty everywhere." A children's story told of the atheist who, while studying a rose, burst out: "What a fool I am! Here I

The PASSION FLOWER Belongs to the class MONADELPHIA and order PENTANDRIA.

From *The Young Botanist* (1835); reproduced in *The Botanizers: Amateur Scientists in Nineteenth-Century America*

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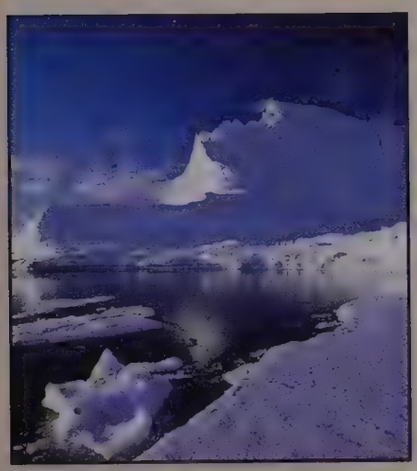

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am trying to make myself believe there is no God when I see the mark of His fingers on everything around me"—and he then burned "his infidel books."

Keeney is often academic in her treatment and tends to keep repeating her points. And she never really communicates the plain pleasure of plant hunting—the excitement over new finds, the exhilaration of being out in nature. But she is blessed with what eighteenth-century naturalists called a curious mind—one given not to idleness but to inquiry—and she livens her accounts with homely details. She catalogs the botanizer's gear: Vials, knives, trowels, a small lens ($1.50 would buy a useful one), and local maps, since the botanizer had a tendency to get lost when absorbed in the hunt; an umbrella, not just to protect the complexion but to shake down nuts and fruits from inaccessible branches and to pull water plants closer to shore; ammonia for insect bites, quinine for malarial areas, brandy for emergencies, and, said one frank manual, "a mild laxative is also desirable." Botanizers prized their self-sufficiency and spurned special equipment. Henry Thoreau, for example, carried his specimens in his hat, and instead of buying plant presses, thrifty collectors used the weighty congressional reports.

Some botanizers became the peers of professionals. To restore his health following imprisonment as a conscientious objector in the Civil War, Cyrus Guernsey Pringle took up plant gathering and amassed an unmatched collection of 50,000 plants native to his Vermont home. Earlier in the nineteenth century, botanizers had useful contacts with professional scientists like John Torrey of New York's Lyceum of Natural History, Asa Gray of Harvard University, and Spencer Baird of the Smithsonian Institution. "Cadres of willing disciples," says Keeney, collected plants for them, sent them their rarer finds, and reported on local conditions. In return, they were given guidance and encouragement. Appreciative botanists occasionally acknowledged the discovery of a new variety by naming it after the botanizer who found it. This was the ultimate reward, and when Asa Gray named a plant after J. G. Lemmon and his wife, Sarah, they reacted, as Mr. Lemmon described it, in "a grand celebration, dancing around the room alternately shouting for joy and weeping with gratitude."

As botany merged into biology and discarded Linnaeus for a more natural and more complex system, a "new botany" was created that emphasized plant phy ology, structure, and relationships. T laboratory worker became more importa than the field collector. The differences b tween botanizer and botanist becar sharper, and the status of botanizing minished. After the Civil War, with urba ization and the growth of industry, Ame cans had more spare time and develop different attitudes about how to use th leisure. They were inclined toward pl and sport, rather than rewarding activi Traditionalists who declared that "a sup ficial study will be of little use" began sound like kill-joys. Gradually, botanizi grew more relaxed and less committed the advancement of science. The innoc science as a popular movement faded a in schools, was changed into a vague ture study, with pupils sprouting beans blotters and growing terrariums on w dow sills.

All through *The Botanizers,* Keen evokes the attitudes of the era. In her m sured way she shows a sympathy for aspirations, intellectual and social, t impelled the botanizers. She skewers eminent scientist who patronized help botanizers by remarking, "The world made up of ordinary men and it is part common sense not to despise their ings." But she does not overlook botanizers' pretensions and snobberi putting down the lady who sniffed t botanizing should not be mistaken gathering flowers, which was "a pasti of the lower classes and the more ignor downtrodden portions of the people of rope." And though she always keep scholar's straight face, a pleased amu ment peeks through when she tells of 1850s feminist who, while out plant hu ing with a gentleman acquaintance, jected to his use of tobacco, while he jected to the bloomers she wore beca they robbed her of her femininity. botanizing brought them together, they parted as friends. "You h promised to give up tobacco and advoc freedom for women, even in dress," wrote him, "and thus shall man be free

The perceptions that lie behind El beth Keeney's substantial work are w make it such a good reminder of h much natural history has both reflec and contributed to the American psych

Joseph Kastner, whose biography of J James Audubon for young readers has been published, has written on the his of natural history in Species of Eter *and* A World of Watchers.

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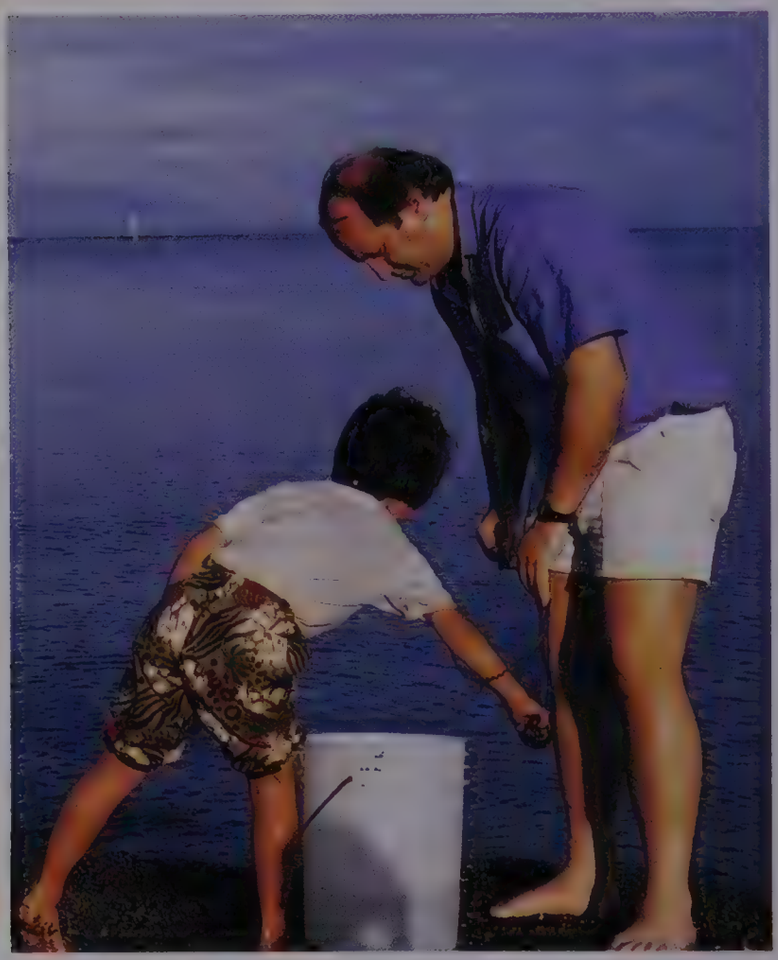
Roommates

Back to back, on a reef near the island of Sulawesi (formerly Celebes) in Indonesia, two male ribbon eels gape and undulate, waving the leaflike sensory appendages on their nostrils. Half-hidden in their burrows, these eels spend hours swaying and gulping, tasting the water for chemicals that emanate from the small fish and crustaceans on which they prey. Flaring nasal palps help direct water into the snout, where cilia aid its flow, then expel it through tubes above the eyes. At the same time, in a separate system for extracting oxygen, the mouth gulps water, expanding the eel's pleated throat. Contracting when the jaws are closed, the

throat pumps water over the gills and then out through an opening behind the jaw. Both these males may not remain males. Ribbon eels are hermaphroditic, and sex change is a normal part of their life cycle. All begin as black juveniles, with the characteristic yellow dorsal fin of the species. When mature, individuals turn a brilliant blue, develop male gonads, and sometimes take up residency with another adult male. Eventually, some will become transformed into entirely yellow females and go on to produce thousands of eggs during their lifetimes.—*R. M.*

Photograph by Mike Severns



An ichthyologist and historian of science, **Theodore W. Pietsch** (page 34) is a professor and curator of fishes at the University of Washington's School of Fisheries in Seattle. Known for his studies of such strange creatures as anglerfish, sea mice, sea moths, and frogfish, Pietsch, above, became interested in the history of marine zoology and enjoys tracking down rare early sources. An acquaintanceship with Lipke Holthuis led him to pursue the story of Lamotius, the subject of their article. "The work could not have been done without Holthuis," writes Pietsch. "He not only found the mislabeled manuscript paintings in Paris and established the identity of their creator, but he translated and made available to me all the primary source materials at The Hague pertaining to Lamotius." Coauthor **Lipke B. Holthuis** spent the first seven years of his life in Indonesia, where his father taught school, then was educated in his parent's homeland, the Netherlands. After graduating from Leiden University, he eventually became curator of crustaceans at Leiden's National Museum of Natural History, where he worked for about fifty years. Retired in 1986, Holthuis still studies the museum's crustacean collections, especially from former Dutch colonies such as Indonesia. In 1959 he became fascinated with the pioneering work of Isaäc Lamotius, the naturalist governor of Mauritius. Through Holthuis's efforts, Lamotius's paintings are published here for the first time.

Writer-photographer **Fred Bruemmer** (page 40) is a frequ contributor to *Natural History.* A veteran traveler of the Arc he has studied its people and wildlife for thirty-five years. Bor Riga, Latvia, in 1929, Bruemmer immigrated to Canada in 19 and worked for a year in an underground gold mine before la ing jobs at a photo studio and a newspaper in northern Onta Bruemmer's love of the Arctic began in the 1950s with trips Lapland and Spitsbergen. His intimate knowledge of the no comes from living with natives for months at a time. Bruemm made his first trip in an umiak, the skin boat featured in this iss in 1975 when he visited Little Diomede Island in the Ber Strait. In 1990 he returned to the island for another season of w rus hunting. This summer he joined an archeologist on Ellesm Island in Canada's High Arctic to investigate the ruins of Eski dwellings abandoned hundreds of years ago. For further inform tion on life on Little Diomede Island see Bruemmer's article "L on a Cold Rock," (*Natural History,* March 1977). For more umiaks, the author recommends Stephen R. Braund's *The S Boats of Saint Lawrence Island, Alaska* (Seattle: University Washington Press, 1988).

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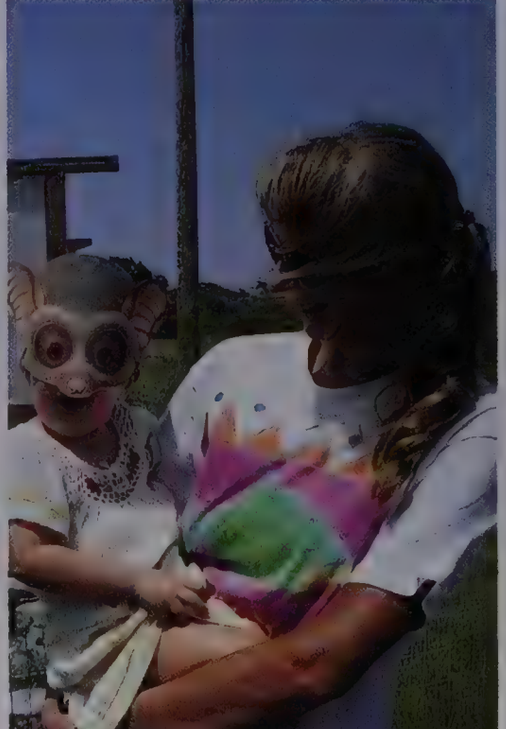
"A pretty face does not get the ram into the truck," comments **Patricia B. McConnell** (page 50) on the judging of border collies. This breed of herding dogs that naturally and enthusiastically tend sheep is evaluated not on looks but on working ability and stamina. An interest in how humans communicate with such working animals led McConnell to study not only herding dogs but also an array of domestic beasts—from camels to geese—and trainers that spoke languages from Farsi to Basque. A lecturer at the University of Wisconsin-Madison, where she received her doctorate in zoology, McConnell also uses her knowledge of ethology and domestic animal–human communication in her applied animal behavior business, Dog's Best Friend. During her doctoral work, says McConnell, "I became so impressed with border collies that I bought one. Since then I got him the most expensive dog toy on the market—a farm and a flock of sheep. Now I raise sheep and border collies and compete in herding-dog trials." For further reading, McConnell recommends Donald McCaig's *Eminent Dogs and Dangerous Men: Seeking Through Scotland for a Border Collie* (New York: Harper Collins, 1991) and for those interested in the study of communication among animals, *Communication,* volume 2 of a series entitled *Animal Behavior,* edited by T. R. Halliday and P. B. Slater (New York: W. H. Freeman and Co., 1983).

An early wanderlust led **Mike Severn** who photographed this month's "Natur Moment" (page 88), to leave his nativ Virginia after only a year of college. H headed for Australia at the age of eightee then hitchhiked across Asia to Europe 1971. Eventually, he settled in Hawaii an completed a B.A. in biology at the Unive sity of Hawaii. In collaboration wit Smithsonian Institution scientists, he ha pursued such projects as plotting the distr bution of tree snails and prospecting f bird fossils in East Maui. Severns is cre ited with discovering seven previously u known extinct flightless bird species, o of which is named after him, and scores other fossil birds. Currently concentratin his photographic efforts on Indonesi Severns photographed the blue ribbon ee on a reef flat near Manado, Sulawesi. H spotted them in four feet of water and ph tographed them with a Nikon F3 wi Aquatica III underwater housing, and tw underwater strobes. Severns and his wif biologist Pauline Fiene-Severns, have ju published their first book of underwat photography, *Molokini: Hawaii's Premi Marine Preserve* (Maui: Pacific Island Publishing).

Anne Brooke (page 60), seen here holding a friendly young mammal, has not always been a bat watcher. Early studies in Finland and the United States led to ten years as a textile designer. She says her interest in bats began in Costa Rica, when she walked under a leaf "tent" of the Honduran white bat. Several years later, after receiving a master's degree from Boston University, she began her study of fishing bats and shortly thereafter fell into the water while watching them hunt. Brooke is currently a doctoral candidate at the University of Tennessee in Knoxville. The focus of her field and laboratory research is the behavior, ecology, and genetics of the fishing bat. For more information on all kinds of bats, she recommends *Just Bats,* by M. Brock Fenton (Toronto: University of Toronto Press, 1983), and *Bats: A Natural History,* by John E. Hill and James D. Smith (Austin: University of Texas Press, 1984).



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11/92

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NATURAL HISTORY (ISSN 0028-0712) is published monthly by the American Museum of Natural History, Central Park West at 79th Street, New York, N.Y. 10024. Subscriptions: $25.00 a year. In Canada and all other countries: $34.00 a year. Second-class postage paid at New York, N.Y., and at additional mailing offices. Copyright © 1992 by American Museum of Natural History. All rights reserved. No part of this periodical may be reproduced without written consent of Natural History. Send subscription orders and undeliverable copies to the address below. Membership and subscription information: Write to address below or call (800) 234-5252 if urgent. Postmaster: Send address changes to Natural History, Post Office Box 5000, Harlan, IA 51537-5000.

Secrets of Siberia's White Lake

How we discovered a new species in a predator's stomach

by Mikhail Skopets

It was the last week in July; another fishery biologist and I were huddled in our little tent in the midst of thousands of miles of northeastern Siberian tundra. Heavy snows, driven by forty-mile-per-hour gusts, whipped our fragile shelter. We spoke little, listening to the whistling winds and the sounds of high waves crashing on the lakeshore twenty feet away. There were no trees or bushes we could burn to keep warm, but I was happy to be at this isolated spot I had long dreamed of exploring.

During my investigations into the distribution and ecology of salmonid fishes, which include salmon, chars, grayling, trout, and whitefishes, my home base had been the Institute of Biological Problems of the North, at Magadan, on the Sea of Okhotsk in eastern Siberia. A seaport built in the 1930s to supply the Kolyma gold mines, Magadan (population 150,000) is not reachable by any roads or trains from the rest of Russia, which we refer to as "the mainland." Unless you are willing to spend weeks on a slow, occasional freighter, the only way to reach it from Moscow is by an eight-hour airplane flight. During the summer of 1978, I was doing fieldwork in Chukotka, about 800 miles to the northeast of Magadan, when I heard from geologists and from the native Chukchi reindeer herders about an interesting site I should investigate. They told me of a remote lake that contained two species of char unlike any they had seen in other lakes.

The following year I persuaded our institute to fund a field helicopter for me to reach this lake, which is about an hour a a half by air from the nearest town. Wi two colleagues, I arrived on July 18, 197 at Lake El'gygytgyn, which means "whi lake" or "ice lake" in the local Chuk language. For ten months out of the ye this lake is entirely covered by ice; spring, it can be six feet thick. Only duri July and August does the ice melt, though in colder years the lake is never e tirely free of large chunks. It is among t coldest continental lakes in the world a can be compared only with Hazen Lake Ellesmere Island in northernmost Canad Near the lake's surface the temperature always only about 34° F, and near the b tom it is no more than 36.5° F.

Fifteen hundred feet above sea level a surrounded by a ring of mountains, the c cular lake is eight miles in diameter a 600 feet deep. Known to outsiders on since the 1930s, when it was first se from the air, scientists at first thought was a volcanic crater. In 1977, howev some geologists from Kiev demonstrat that the lake bed was actually an impa crater formed when a huge meteor smashed into the mountains about 3.5 m lion years ago. Of the earth's mete craters younger than 4 million years old is believed to be the largest.

Our little expedition lived in tents by t side of the lake for three weeks. That ye in Chukotka the weather was very ba two snowstorms in July and eight in A gust, sometimes with temperatures bel zero. We found only one big predato char, of a known species, and then friends had to return to Magadan. I

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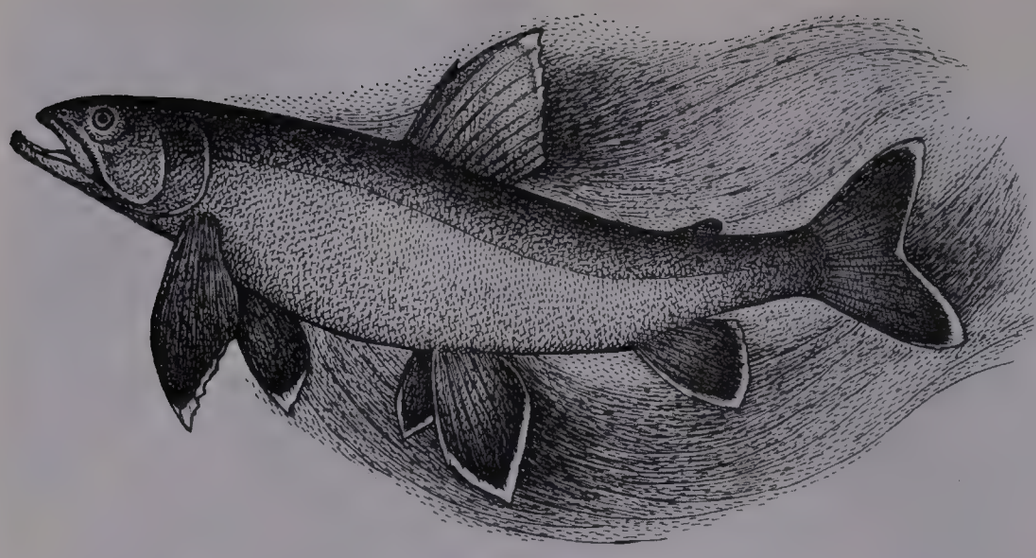

A male longfin char
Patricia J. Wynne

mained for another month, and by the first days of September, I had caught 200 specimens of a small char, which later turned out to be a previously undescribed species. During this period, the little char began to spawn and many ventured near the shore, where I easily caught them in my gill nets at a depth of only ten feet. In 1981 we published the description of these smallmouth char, *Salvelinus elgyticus,* which we named after the lake. This fish, we later found, lives on the sloping bottom, from the shoreline to a depth of about 300 feet, where it feeds only on zooplankton.

Near the end of summer, I used spin tackle and a lure (a perfectly respectable method of collecting scientific specimens) and caught a twelve-pound char. In its stomach I found some remains of small fishes and collected fragments of their skulls. Later, during the winter, I showed these bones to one of my colleagues, an expert in the morphology of salmonids. He told me some were from the smallmouth char, but that others were from a species he had never seen before. So now we knew that there was a third form of salmonid fish in this unusual lake—perhaps also unknown to science.

It took another six years before I was able to get the funds to return to Lake El'gygytgyn. On August 20, 1985, four scientists from our institute (with only one other ichthyologist, Igor Chereshnev) flew to the lake for a ten-day stay. Our only way of exit would be to float in an inflatable boat 250 miles down the single river outlet of the lake to the nearest village, racing to beat the onset of winter. I set my gill nets near the shore, but all I caught were the two species I had seen before: the large, predatory char and the smallmouth form we had discovered six years earlier. In the stomachs of the predators, I again found some partly digested bodies of the third, unknown species. We were really excited because we felt we were closing in on the creatures, but these decomposing corpses were not complete enough for a good scientific description.

It occurred to me that perhaps these elusive fish lived only at a great depth, where they were eaten by the big char, so I determined to set my gill nets more than 200 feet deep. In the morning, in the midst of a windstorm, I went out about half a mile in the inflatable boat to locate my buoy marker. I had some difficulty pulling the nets up but was overjoyed at what I found: about sixty individuals of the unknown species, a salmonid with very unusual body shape and colors.

Without the distinctive feeding habits of the large predatory char, we might never have known of the existence of the elusive, deep-dwelling species. The lake is so cold that this large char, which catches its prey mostly at great depths, has developed the habit of coming up and staying near the warmer (43° F to 46° F) mouths of small tributaries in order to digest its food.

The ecosystem of this lake appears to be very simple. The food chain goes from algae to zooplankton, then to small fishes, and finally to big predatory fishes—an ecosystem similar to that of the open ocean; most lakes have more complex systems, involving fishes that prey on bo tom-dwelling invertebrates.

Later, we discovered that the predator dinner, of which we now had scores of ur damaged examples in our nets, belonge not only to a new species but to an entirel new genus. Most genera of salmonids ha been described in the nineteenth century only one more had been added during th 1930s. Our newly discovered species wa noteworthy not only for its shape and i place in the ecosystem but also because may be the most primitive representativ of its group. In 1990, after a detailed stud of its anatomy, specialists concluded tha the species is closer to the ancestors c chars than any other living salmonid.

Because of its ample fins, we gave it th name *Salvethymus svetovidovi,* longfi char. Our genus name, *Salvethymus,* ind cates that it looks like something betwee a char and a grayling, although it is not hybrid. Our largest specimen was onl thirteen inches long and weighed about pound, yet it was thirty years old—dete mined by counting the annual rings on th small stones (otoliths) in the inner ear.

Longfins live mostly beneath 200 fe of water and inhabit the entire lake, in cluding its deepest part. They are near-bo tom feeders that eat mostly zooplankto and sometimes small amphipods. Whi short-finned, long-bodied trout make fas straight runs when feeding, the shape the longfin char allows precise movemen when capturing very small prey witho moving far. Although they can spawn a year round, most longfin char lay the eggs in May and June, about 300 fe under the ice.

All the species in Lake El'gygytgyn a well adapted to extreme cold. During th periods of Pleistocene glaciations, Ch kotka was not covered by ice shields was North America, but developed patch glaciers in valleys, like those in the prese Himalayas or Rocky Mountains. Many the region's lakes were carved by the local glaciers, but Lake El'gygytgyn's m teor crater was an exception. Under thi ice, but not destroyed by glaciers, i ecosystem has persisted without interru tion for more than 3 million years, maki it a sort of "lost world" preserve. In con parison, most Canadian lakes have ec systems that have been functioning co tinuously for only 10,000 years or so.

When I brought some small lake inve tebrates back to the institute, some them, too, turned out to be previously u known in the scientific literature. I was n surprised.

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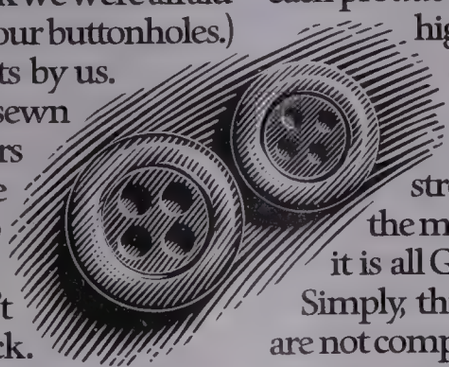

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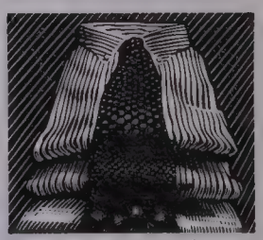

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What Is a Naturalist, Anyway?

In a perplexing time, a writer contemplates his grandfather's "old-fashioned" science

by John T. Nichols

One of my earliest wonderful memories is of riding on a Long Island Rail Road train in the late 1940s. I am seated beside either my dad, David Nichols, or my grandfather John T. Nichols, after whom I am named. We are going to spend a day at the American Museum of Natural History in Manhattan, where Grandpa was curator of fishes for many years. My excitement and anticipation are boundless.

As I recall it through a small child's eyes, my grandfather's office at the Museum was a magical and chaotic place featuring stacks of books and papers, messy ashtrays full of burned pipe tobacco, and countless bottles and jars of pickled fishes. I don't recall any of my conversations with the old guy on those occasions—in fact, I recollect that he was a fairly taciturn bloke when it came to small, hyperactive children. Yet he allowed me free rein to poke about, gawk, and of course, ask endless questions, such as, "What is this weird thing, Grandpa?" and "Wow, what is *that* funny looking thing?"

Granted, I have no tape recordings of his replies, but I suspect they were more or less like the answers my father, who was inspired to be a naturalist by his father, often gave to similar queries. Namely, "That's a *Rana grylio,* John," and "That's a *Storeria occipitomaculata.*" And of course, "We call that *Lucanus elephus.*" Hence, at an early age I was forced to learn how to translate Latin into real language, such as "That's a big green frog," and "That's a little snake," and "That's a fat black beetle with very big pincers." In this manner I first became enamored of, and privy to, the incredible secrets of the natural world.

When I think back to who first inspired me to delve into that world, it's hard to differentiate between my tall, skinny grandfather and my tall, skinny dad. The genetic, spiritual, and intellectual lines of connection pass directly from my grandfather through my dad to me, and of course I have since bequeathed the passion to my own children.

In my early childhood, the best thing about being a budding naturalist was that you got to kill things and inspect them close up. I know that the indiscriminate application of this practice is frowned upon today, since the rare snaffular grosbeak that one shoots and prepares for a museum collection is liable to be the last of its species. But back in those profligate days, when nature was still in flower, if one wished to understand better the marvels of life on earth, one went out and harvested living things by abrogating their life expectancies with an abrupt application of extreme prejudice.

One could also mix epicurean delights with scientific research. For example, here's one of my favorite passages from my grandfather's journals, dated August 21, 1915:

> We got up before dawn and crossed the bay to Little Beach Point for snipe. It was a bad morning, nothing doing. After a time a single large bird, which might have been a Greater Yellowleg came in with steady flight, high up. I pronounced it a Willet, and...did not, until late in the evening of the following day, after having gone through the painful process of making a skin of it, and having eaten my share of the succulent bird, realize my mistake. Then, starting to measure the skin for eastern or western race of Willet, I...became suspicious of its identity and promptly determined it as Ring-tailed Marlin.

I would suppose that after making a number of observations in this manner, my grandfather eventually was able to distinguish between a marbled godwit and an igneous avocet by using his educated palate rather than a field guide, provided that he had not ladled on too much garlic during the preparation of the specimen.

Only a week later, my grandfather was again out observing nature, this time accompanied by his good friend, noted ornithologist Ludlow Griscomb (who was also a prominent member of the Linnaean Society). To quote JTN's notebook:

> In the afternoon with an easterly coming on we found two Northern Phalarope on t weed in Beach Point Cove. In the ear morning of the 30th after the storm, pr sumably the same two birds were still ther They were very tame and when flushed fle only a short distance before alighting agai L.G. tried unsuccessfully to "harpoon" o with a paddle of the canoe.

Now, I myself was never prone to ha pooning phalaropes with canoe paddles the name of science; I much preferred attack them with a slingshot—at least un I was old enough for BB guns. Eventuall I outgrew my lust for death, however, a many a tiny bird or scurrying little mar mal breathed easier after my conversion

Nevertheless, I shall always be ve grateful that as a child I had access to t close-up study of those moribund critte My proximity to countless organism pickled in jars or stretched out on mour ing boards created in me a fascination th has led me to spend much of my adult li agitating on behalf of animals.

In my grandparents' attic in Gard City, Long Island, there was a treasu trove of specimens that I always inspect first thing whenever we went to vis These were mostly oceanic birds that m grandfather had collected in his young days during his two voyages around Ca Horn. But it was at my grandparents' sum mer home in Mastic, on the south shore Long Island, about sixty miles east of Ne York City, that I really went to town. that old house was a fantastic collection stuffed birds, including a stately great bl heron, which in memory looms taller th myself. Beside it were all sorts of ducks ring-necked pheasant, numerous shor birds in the sanderling/sandpiper/plov category, and a rare and imposing snow owl. And there was a large butterfly a insect case, which I guarantee still has m greasy childhood fingerprints pressed i delibly into the glass.

The Mastic estate consisted of 6 acres of virgin forests and fields, most which is still preserved as a historic monument and conservation area. I spe

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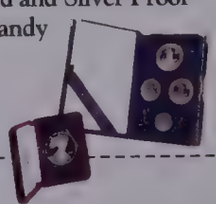

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all my days there avidly collecting things. Among the wild charms of the place was a colony of native box turtles that roam the grounds to this day. For decades, my grandfather had marked the shells of individuals with identifying codes, and he actually paid for turtles that I and other family members brought in (*see* "Evidence of Things Seen," *Natural History,* June 1988). And as any naturalist knows, a love of the natural world is always enhanced when there's a bit of filthy lucre at the end of a day spent in the field.

I also gathered bats from behind the window shutters of the old colonial house at Mastic and plucked monarchs and skippers from the butterfly bushes planted around it. I gathered thousands of tiny hoptoads in cardboard boxes and watched them for hours as they scriggled about. I climbed down into the icehouse to retrieve rabbits that had fallen in. And using a flashlight and a gob of peanut butter in a mayonnaise jar, I caught live mice in one of the barns, collecting a dollar a mouse from my dad, until he realized I had enough skill to catch thousands and he canceled the reward. I also helped my father run traplines for small mammals and would sit at a table, enthralled, while he and/or my grandfather prepared them as specimens.

My grandfather and my father spent many hours in blinds photographing birds, but most often they strolled about the Mastic woods and wetlands, hardly missing an insect, flower, or birdsong. I followed and I listened. Whenever a bird went "tweet," my dad or grandfather said, "Hmm, there's an ovenbird" or "Yup, a red-eyed vireo" or "Hear that hermit thrush?" Naturally, they usually added absent-mindedly, "*Seiurus aurocapillus*" or "*Vireo olivaceus*" or "*Catharus guttatus*." If I picked up a feather, they almost immediately gave it an identification: "towhee," "bluejay," "osprey." Almost anything I stumbled upon they could identify, quantify, or categorize, be it animal, vegetable, or mineral.

As a result, I had feather collections, butterfly collections, leaf collections, an eggshell collection, a bird's nest collection, a snakeskin collection, a skate's egg collection, a seashell collection, a beetle collection. You name it, I had it—displayed in a box, in a Riker mount, or on a shelf. I also had my own frogs, snakes, minnows, tadpoles, and newts pickled in jars. My father and grandfather were quite free with naphthalene, formaldehyde, and arsenic (to cure the pelts of little animals). I probably could have wiped out a small city by dumping the lethal chemicals of my arsenal into the local water supply.

Another activity at Mastic was collecting animal tracks. We poured melted paraffin into a fox's or deer's or raccoon's footprints, encircling the casting with a tin can from which both ends had been cut. Then we pressed the wax form into a dish of plaster of Paris, and—*voilà!*—the tracks were transformed from soft mud originals into hard copies. I was also intrigued by animal scat because my father and grandfather saw nothing wrong with squatting and intimately inspecting fox droppings or owl pellets and commenting at length on the dietary habits and intestinal fortitude of the excretor involved.

So one of the traits that marked my grandfather, and that he passed on to my dad, who passed it on to me, was his curiosity about almost everything in the natural world. Grandpa was an eclectic man of science. To earn a living, he wound up specializing in fishes, but he was also an avid and respected ornithologist, a fan of weasels, a good man with a bat (the flying kind), a turtle junkie—and was intrigued by almost everything else. In a 1916 article entitled "Primarily Unadaptive Variants," he ran through a wide gamut of discussion, including observations on black-backed gulls and Spanish mackerels, tree squirrels and bay-breasted warblers, black bears and wild guinea pigs.

The man was also a philosopher and poet, and he had a sometimes wacky sense of humor. The same mind that ranged so widely over the mysteries of natural history was also capable of conjuring up my favorite poem of childhood:

I had a niece
Who ate a piece
Of candle grease.

For goodness sake,
How it did it make

John T. Nichols, with the author, John T. Nichols II, left, at the family's estate in Mastic, New York, 1941.
David G. Nichols

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Her stomach ache.

Run, run, anyone
Get a gun.

Because we love her
We can't let her suffer,
We'll shoot her and stuff her.

All these reflections on my grandfather lead me to ask, "What is a naturalist, anyway?" This same question was asked by my Grandpa in a short autobiography he wrote in 1923. He answered his own query in this manner, and it is the way he defined himself:

A naturalist, it would seem, is one interested in natural phenomena. The term may be further limited, however. All persons working in the broad field of science deal with natural phenomena, but the modern tendency to specialization has carried the majority of scientists into fields of thought far removed from those of the old-fashioned naturalist; and in the study of animals, for instance, there are anatomists, cytologists, physiologists, geneticists, etc., so numerous, that in its narrower sense it is convenient to reserve the term naturalist for those investigating life from an older, different viewpoint. A naturalist takes the most obvious first phenomenon, the individual animal, for the basic unit of his science, and instead of cataloguing its parts, investigates its place in nature, and that of the larger units, such as the species, of which it is an integral part.

My grandfather's definition of a naturalist reminds me of a statement by John Muir, which I feel best describes the situation of all life on earth. Muir said, "Whenever we try to pick out anything by itself, we find it hitched to everything else in the universe."

Of course, that's obvious, and it should be the first building block of all knowledge. Yet in a world that has reached its current technological ascendancy largely through specialization, we have all but forgotten that nothing exists apart from everything else. And so we find ourselves in a major-league pickle that features a diminishing ozone layer, the greenhouse effect, and perhaps ultimately, the premature end of most evolution on earth.

The responsibility of scientists in this dilemma was emphatically driven home to me some years back when I was working with the European film director Costa-Gavras on a movie (never produced) about the daily lives of some nuclear physicists. All of them were brilliant, dedicated, and compassionate people, but their dependency on government money for the perpetuation of their scientific specialties ultimately led them to create a technology of

egadeath. During my research for this m, I repeatedly came across warnings by arious knowledgeable authors on the anger of the growing chasm between uman values and the scientific enterprise. iologist Jacques Monod, for instance, roclaimed that "any mingling of knowlge with values is unlawful, forbidden." ociologist Max Weber put it this way: Whoever lacks the capacity to put on inders, so to speak…may as well stay way from science." And science historian teve J. Heims once wrote that "in the neteenth century, any consideration of ocial responsibility in connection with cientific research became a direct violaon of the standards and values of the proession. Thus, falling into a false innoence was the price paid for 'benefits' of cientific progress."

Two of the more interesting thinkers I et in my reading were the astrophysicist reeman Dyson and the physicist Max orn. In his book *Disturbing the Unierse,* Dyson speaks of how some modern olecular biologists have adopted a narow definition of scientific knowledge, "by educing the complex behavior of living reatures to the simpler behavior of the olecules out of which the creatures are uilt…[results in a] reduction of the aparently purposeful movements of an oranism to purely mechanical movements f its constituent parts." Elaborating on ow this tendency has transformed the enre modern workplace, Max Born says at "most workmen know only their spel tiny manipulation in a special section f the production process and hardly ever ee the complete product." So, "naturally, ey do not feel responsible for the prodct or its use." Born then states that this ind of technical specialization, which separates action from effect," reached its enith in Nazi Germany, where mass murerers "pleaded not guilty because they did their job' and had nothing to do with s ultimate purpose."

While Born felt that scientific research as led to an enormous widening of the orizon of knowledge…this gain is paid for y a bitter loss. The scientific attitude is apt o create doubt and skepticism toward tradional, unscientific knowledge and even toard natural, unsophisticated actions on hich human society depends.

Born concludes:

am haunted by the idea that this break in uman civilization caused by the discovery f the scientific method may be irreparable. he political and military horrors and comlete breakdown of ethics which I have witessed in my lifetime may be not a symp-

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tom of social weakness, but a necessary consequence of the rise of science—which in itself is among the highest intellectual achievements of man.

Now it may seem that I have strayed a bit far afield from my tall, lanky grandfather, dressed in a rumpled blue suit and a tattered old fedora, with a pipe hanging out of his mouth, squinting as he notched yet another box turtle and then leaned over slowly to set it free in the grass. Yet I have always felt that in that man, and in the legacy he passed on to my father and thus to me, there was an important lesson to be learned. It was evident in his strength of character, in his personality and his view of the world, in the disciplines he chose to follow, in the curiosity he had for many things, and in the humility that typified his way of doing science. But most importantly, my grandfather saw the natural world as an interconnected whole: he understood, and sympathized with, "the complete product."

Today, science is much more sophisticated than he ever could have imagined. Yet in this world of vast complexity, instant communication, and technological sophistication, we seem to have completely lost track of the overall scheme of things. This has led to what many see as a building ecological catastrophe, perhaps of insurmountable proportions. And interestingly, it seems as if my grandfather's perception of the world, placing value on biodiversity, is increasingly one that the environmental movements of today are adopting as their own in order to save the globe. At a recent meeting of the American Society of Ichthyologists and Herpetologists, an organization that my grandfather helped to found, between a fourth and a third of the presentations dealt with conservation, endangered species, environmental damage, biodiversity, species protection, and the relationship of "anthropogenic perturbation to the extirpation of species." I find that both sad and hopeful. Sad because, obviously, each day there are many fewer snakes and fishes and salamanders out there to learn about. (Approximately 3,000 species became extinct in the United States alone last year.) But I also feel hopeful because obviously the conscience of science today is struggling to learn how to rectify the situation.

In a book called *The Tangled Wing,* the biological anthropologist Melvin Konner writes, "We are losing the sense of wonder, the hallmark of our species and the central feature of the human spirit." And he believes that:

at the conclusion of all our studies we must try once again to experience the human soul as soul, and not just as a buzz of bioelectricity; the human will as will, and not just a surge of hormones; the human heart not as a fibrous, sticky pump, but as the metaphoric organ of understanding.

I think my grandfather probably always operated on those presumptions. He was awed by the mystery of things. And he never could ignore his own emotional responses to a beautiful seascape or butterfly simply because he understood a great deal about the factual components that made it beautiful.

So, "What is a naturalist, anyway?" Well, I would propose that a naturalist is a person whose curiosity is boundless. He or she is interested in kinkajous and sticklebacks, in astronomy, French wine, magpies, baseball, prairie rattlesnakes, quantum mechanics, corn on the cob, great sperm whales, and even Bolsheviks and hummingbirds. A naturalist is a person who tries to delight in everything, is in love with the whole of life, and hopes to walk in harmony across this earth. A naturalist might also be a lunatic like myself who would like to overthrow an economic system based on planned obsolescence and conspicuous consumption because he believes that it is a formula for planetary suicide. Put another way, a naturalist probably understands that human growth for the sake of growth is the ideology of the cancer cell. So a naturalist most likely gets a vasectomy or a tubal ligation after 1.8 children and sends lots of money to Planned Parenthood. In a naturalist's lifestyle, a lot less "stuff" is consumed, so that all the other critters he or she loves can use that unexploited biological capital for their own benefit and survival.

In short, a naturalist chooses not to be anthropocentric, believing, rather, that everything has an equal right to life on earth—whether it's an elephant, a peasant from El Salvador, an African cichlid, or a tiny bacterium. A naturalist understands, and defends, the product as a whole. I feel certain that the answer to our future lies in this world view. And I am grateful I learned it as a child, because it has enriched my life immeasurably.

Novelist-screenwriter John T. Nichols is author of The Milagro Beanfield War *and most recently of an environmental photo essay,* The Sky's the Limit. *This article is adapted from his keynote address at an American Society of Ichthyologists and Herpetologists meeting, held at the American Museum of Natural History.*

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"Red in Tooth and Claw"

Few scientists know of the thinking and pain behind the most overused one-liner in biology

by Stephen Jay Gould

If buttercups buzzed after the bee
If boats were on land, churches at sea
If ponies rode men and if grass ate
the cows
If cats were chased into holes by
the mouse...

"Then all the world would be upside down"—an apt description of his plight, or so Cornwallis undoubtedly thought when he instructed his pipers and drummers to play this ditty during his surrender to Washington at Yorktown (the Americans responded with "Yankee Doodle").

Such reversals of established order intrigue us for their challenge to our "safe" assumptions. I keep a file for biological examples—carnivorous plants, worms that eat frogs, marine phytoplankton (single-celled, photosynthetic forms) that release toxins to poison fish and then digest flecks of tissue dislodged from the dying vertebrates (see report in the July 30, 1992, issue of *Nature*). This month marks the hundredth anniversary of another curious reversal, sociological this time but from the heart of British science. The November 1892 edition of *The Nineteenth Century,* perhaps the leading British review of the time, published a series of tributes to Alfred, Lord Tennyson, the poet laureate who had died the month before. A memorial from Thomas Henry Huxley—in verse—led the parade. This tribute has never won any prizes for rhyme or meter, but I still delight in the thought that Britain's leading scientist chose to honor Tennyson in the poet laureate's own medium. Huxley spoke of Tennyson's company in Westminster Abbey, undoubtedly evoking his old friend Darwin as exemplar of the last couplet:

And lay him gently down among
The men of state, the men of song;
The men who would not suffer wrong;
The thought-worn chieftains of the mind;
Head servants of the human kind.

But why did Huxley choose to memorialize Tennyson? They knew each other only slightly. Both belonged to the Metaphysical Society, an elite club of Victorian intellectuals, but Tennyson almost always remained silent at meetings. Tennyson liked Huxley, but recorded only two visits of the scientist to his home. Huxley resolves this riddle for us in a letter to the secretary of the Royal Society (Britain's leading association of scientists), urging that an official representative be sent to Tennyson's funeral. Huxley honored Tennyson from general respect, not personal friendship:

> He was the only modern poet, in fact I think the only poet since the time of Lucretius, who has taken the trouble to understand the work and tendency of the men of science.

Even so, why should this series of columns, devoted to evolutionary subjects, choose the old device of a funerary centennial to honor Tennyson? His general interest in science will not suffice, especially in the light of other monumental events in 1892, equally worth memorializing: the election of Grover Cleveland, the birth of Haile Selassie, Monet's beginning of the Rouen Cathedral paintings, the pugilistic victory of Gentleman Jim Corbett over John L. Sullivan, and the composition and first performance of "Ta-ra-ra boom-de-ay."

I choose Tennyson (and have, in fact, been looking forward to this excuse for several years) for a very definite and parochial reason. Many subjects have canonical descriptors, snippets of phrase that, in knee-jerk fashion, identify the item with all the immediacy of a psychiatrist's test in word association. If I say "the Georgia Peach," you will reply "Ty Cobb" (if you know anything about baseball). If I say "the Big Apple," you will reply "New York City" (if you know anything about anything). Darwinian evolution also has a canonical descriptor, this time, a snatch of poetry: "Nature, red in tooth and claw."

Every evolutionist knows the line. It slips out in lecture after lecture, article after article—even following that New Year's pledge never to quote the cliché again. Its parodies are also legion. My colleague Michael Ruse, for example, once subtitled a book about Darwin's intellectual struggles with his contemporaries: *Science Red in Tooth and Claw.*

Every evolutionist can cite the line (we would draw and quarter any impostor who couldn't); we all think that it describes a biological world reconfigured by evolutionary theory; nearly all of us know that it began as a line of poetry; most of us are aware that Tennyson is the source; I suspect half of us even know that it comes from *In Memoriam*; I'll bet a thousand bucks that fewer than one in a hundred of us have ever read the poem (and I stood among the ninety-nine until last week). Don't be too quick with your opprobrium. *In Memoriam,* after all, is not a Haiku with seventeen syllables, or a sonnet with fourteen lines. *In Memoriam* runs to 131 sections and more lines than I care to count (filling eighty pages in my edition). And these days, long Victorian poems are not high on the hit parade, even of most serious intellectuals. So, initially, I decided to write this essay in the year of Tennyson's centenary in order to discover for myself—and to convey to my colleagues and

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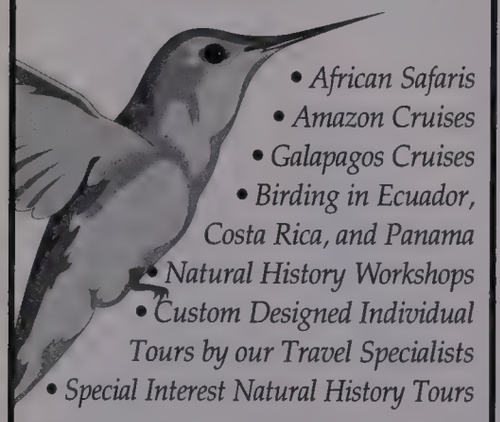

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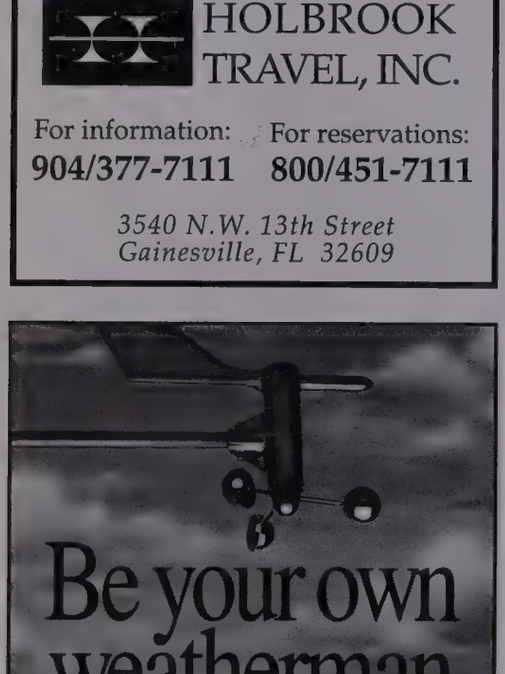

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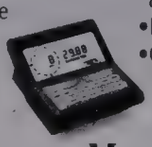

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readers—the actual context of a line that we have repeated too often and without any background. As so often happens, the story became broader and more interesting as I probed.

Tennyson was born in 1809, the same year as Darwin. As an undergraduate at Trinity College, Cambridge, he met Arthur Hallam, handsome and brilliant son of the historian Henry Hallam. Their ardent friendship was clearly the key emotional experience of Tennyson's life. (I will not speculate on its nature, and the literature continues to maintain a discreet silence, largely for lack of evidence—for Hallam's father destroyed all his son's letters to Tennyson, while Tennyson's son later burned all Hallam's letters to his father. Arthur Hallam was engaged to Tennyson's sister at the time of his death, so complexity probably reigned, but if the intense bond between Arthur Hallam and Alfred Tennyson didn't have at least a repressed sexual basis, then…well, I'll be a monkey's uncle.)

On October 1, 1833, Tennyson received a letter from Henry Olden, Hallam's uncle, and his world collapsed:

> Your friend, Sir, and my much loved nephew, Arthur Hallam, is no more—it has pleased God to remove him from this his first scene of Existence, to a better world, for which he was created. He died at Vienna on his return from Buda, by apoplexy—and I believe his Remains come by sea from Trieste.

Arthur Hallam was twenty-two years old when he died.

In Memoriam, published in 1850, is Tennyson's extensive tribute to this extraordinary friendship, and to the emotional, religious, and philosophical meaning of such loss. (Tennyson originally published anonymously—although his distinctive authorship didn't elude a soul in the know—under the full title *In Memoriam A. H. H. Obit* [died] *MDCCCXXXIII.*) The poem was an instant success and surely played a large role in Tennyson's appointment (following the death of Wordsworth) as poet laureate later in 1850. Queen Victoria and her husband, Prince Albert, especially liked the poem. After Albert's death in 1861, Victoria regarded *In Memoriam* as important solace in her extended grief. "Next to the Bible," she stated, "*In Memoriam* is my comfort." She even altered one of Tennyson's verses in her private copy, substituting "widow" for Tennyson's "widower" and "she" for "he"—so that the lines could be recast as mourning for Albert:

> Tears of the widow, when she sees
> A late-lost form that sleep reveals,
> And moves her doubtful arms, and feels
> His place is empty, fall like these.

Victoria requested (I think one says "commanded") a visit from Tennyson in 1862, and later wrote in her diary:

> I went down to see Tennyson who is very peculiar looking, tall, dark, with a fine head, long black flowing hair and a beard—oddly dressed, but there is no affectation about him. I told him how much I admired his glorious lines to my precious Albert and how much comfort I found in his *In Memoriam.*

With this background, we can grasp the setting for Tennyson's famous image of "Nature, red in tooth and claw." And we can understand why evolutionists have so misinterpreted the phrase as either a harbinger or a description of Darwin's world. First of all—and sorry to sound so defensive—the error is not entirely our fault. (The most basic of all facts can make evolutionists seem mighty stupid when they argue that Darwin's new formulation inspired Tennyson's line—for *In Memoriam* appeared in 1850, while Darwin kept his views close to his chest before publishing *The Origin of Species* in 1859.) A long tradition of literary criticism has read evolution into the biological passages of *In Memoriam* and the uniformitarian geology of Lyell into Tennyson's lines about the earth and its historical changes. Dutch historian of science Nicolaas A. Rupke presents an extensive list of such literary citations and writes (in his important book *The Great Chain of History,* Oxford University Press, 1983):

> It has become customary to read in…*In Memoriam* not only organic evolution, but also the geology of…Lyell. Because the relevant sections were written…long before Darwin's *Origin of Species*…some literary critics have interpreted these passages as an anticipation of the theory of organic evolution by the intuitive genius of a poet, before the analytical mind of Darwin dared to arrive at the same conclusion. "How did the poet come to forestall the scientists in their own game?" one critic asks.

If *In Memoriam* is a grieving man's quest for peace, transcendence, renewed faith, resolution, acceptance, or whatever (all and more have been proposed), then what role does science play in this search—and remember that Tennyson was a champion of science, not an embodiment of the unjust (and probably nonexistent) stereotype of an affected, antitechnological, romantic poet. The scientific verses of *In Memoriam* are among the

ıost famous, and critical commentary has lways viewed them as essential to the arrator's quest in the poem.

Tennyson dismisses a silly argument bout science, the kind of sophistry woven y such tormentors as Job's "comforters." low can any grieve so deeply in a world ıade so exciting by scientific advance:

A time to sicken and to swoon,
When Science reaches forth her arms
To feel from world to world, and charms
Ier secret from the latest moon?"

ennyson replies with two affecting erses, also invoking an image from naıre. How can you compare a happy genrality with my private desolation:

ehold, ye speak an idle thing;
Ye never knew the sacred dust.
I do but sing because I must,
nd pipe but as the linnets sing;

nd one is glad; her note is gay,
For now her little ones have ranged;
And one is sad; her note is changed,
ecause her brood is stolen away.

Tennyson's serious examination of naıre as a possible source of solace occuies a crucial place in three consecutive ections (54–56), just before the poem's ıidpoint. In section 54 (which I shall uote in full), Tennyson uses the first four erses to express a standard argument of ıe "natural theology" so popular in the eneration just before his—that good must e behind nature's apparent evil:

), yet we trust that somehow good
Will be the final goal of ill,
To pangs of nature, sins of will,
)efects of doubt, and taints of blood;

hat nothing walks with aimless feet;
That not one life shall be destroyed,
Or cast as rubbish to the void,
Vhen God hath made the pile complete;

hat not a worm is cloven in vain;
That not a moth with vain desire
Is shriveled in a fruitless fire,
)r but subserves another's gain.

ehold, we know not anything;
I can but trust that good shall fall
At last—far off—at last, to all,
nd every winter change to spring.

Nicely said; but then, as a stunning reersal in the last verse, Tennyson labels ıis conventional belief a vain reverie:

o runs my dream; but what am I?
An infant crying in the night;
An infant crying for the light,
nd with no language but a cry.

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The narrator must now examine nature more honestly—as Tennyson does in section 55. In some of the poem's most famous lines, Tennyson expresses a theme that would be important to Darwin (although scarcely original with him), and that strikes the narrator as such a mockery in his grief: why does nature, while preserving stability of species, permit such a hecatomb of individual and untimely deaths:

Are God and Nature then at strife,
  That Nature lends such evil dreams?
  So careful of the type she seems,
So careless of the single life,

That I, considering everywhere
  Her secret meaning in her deeds,
  And finding that of fifty seeds
She often brings but one to bear.

Tennyson then looks to large scales for an answer. Perhaps the carnage of individuals (like Hallam) subserves a larger good over eons:

I stretch lame hands of faith, and grope,
  And gather dust and chaff, and call
  To what I feel is Lord of all,
And faintly trust the larger hope.

But Tennyson is not optimistic; he has already labeled this solution as a "faint" hope. He then opens section 56 with my favorite lines of all, the geological verses of *In Memoriam*. Nature mocks his own observation in section 55 by showing that, in the fullness of time, even species must die. "All shall go," and momentary suffering supports no permanent stability:

"So careful of the type" but no.
  From scarpèd cliff and quarried stone
  She cries, "A thousand types are gone;
I care for nothing, all shall go.

"Thou makest thine appeal to me:
  I bring to life, I bring to death;
  The spirit does but mean the breath:
I know no more."…

And so, we finally come to "Nature, red in tooth and claw." One hope still remains: nature may savage individuals and eventually remove species, but does this carnage (however paradoxically) eventually lead to human nobility and the soul's immortality? Tennyson, in a long question spread through four verses, answers "no" and, invoking the famous image, even chides the narrator for imagining such a solution in the light of nature's factual rapacity:

…And he, shall he,
Man, her last work, who seemed so fair,
  Such splendid purpose in his eyes,
  Who rolled the psalm to wintry skies,
Who built him fanes of fruitless prayer,

Who trusted God was love indeed
  And love Creation's final law—
  Though Nature, red in tooth and claw
With ravine, shrieked against his creed—

Who loved, who suffered countless ills,
  Who battled for the True, the Just,
  Be blown about the desert dust,
Or sealed within the iron hills?

Later in the poem, as the narrator resolves his grief, Tennyson does take comfort from the progressive pathway that he infers from geological history. "Contèmplate all this work of Time" he states in beginning section 118. Perhaps the ancient dead are harbingers of better things to come: "But trust that those we call the dead / Are breathers of an ampler day / For ever nobler ends." He then describes geological history—an earth that "in tracts of fluent heat began…Till at the last arose the man…The herald of a higher race." The section ends with a plea for human betterment:

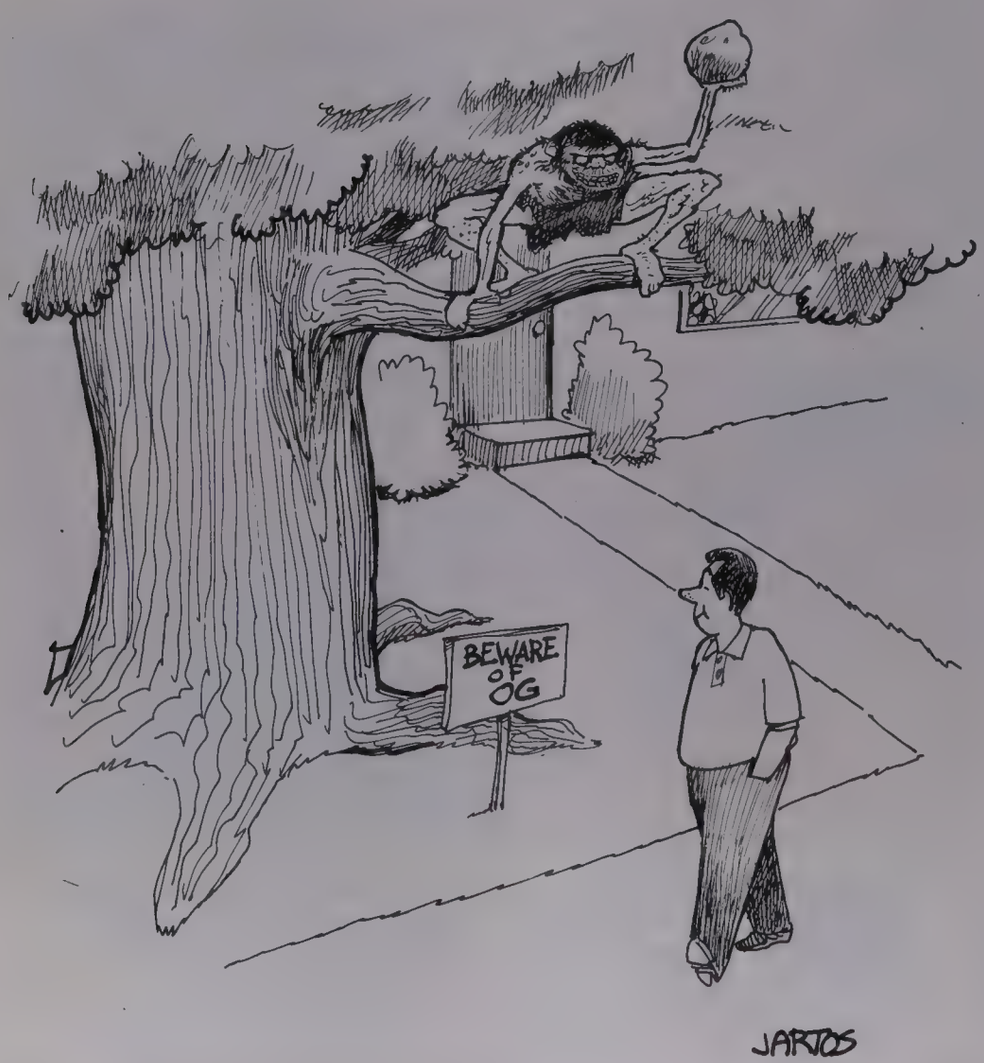
Move upward, working out the beast,
And let the ape and tiger die.

(I assume he means the ape and tiger within us and that these lines are not pro-hunting propaganda!)

Tennyson ends *In Memoriam* (section 131) with a happy epithalamium (a fancy name for a marriage ode). He returns to the theme of historical progress and compares the growth of the child that will issue from this marriage with advance of the race: "And, moved through life of lower phase, / Result in man, be born and think." This ray of comfort, drawn from nature at the very end of the poem, may strike us as hokey today, but I am inclined to respect any rationale invoked (however tenuously) to describe a gain of emotional peace by someone who has grieved so long and deeply. Tennyson argues that modern humans are in transition to some higher stage, that our current sufferings aid this progress, and that Hallam was a premature representative of these nobler beings:

No longer half-akin to brute,
  For all we thought and loved and did,
  And hoped, and suffered is but seed
Of what in them is flower and fruit;

Whereof the man that with me trod
  This planet was a noble type



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Appearing ere the times were ripe,
That friend of mine who lives in God.

The sources of these "nature passages" have almost always been misconstrued because we remember and honor supposed "winners" and forget the scientists now branded as wrong. Tennyson's biology is almost always viewed as evolutionary and his geology as following Lyell's uniformity of slow and steady change. In fact, as Rupke shows so well (and as should be clear to anyone who reads *In Memoriam* with adequate knowledge of British nineteenth-century geology), both facets of Tennyson's natural history derive from a single and different source—the progressivist and catastrophist geology that represented the main line of early nineteenth century thought (and that Tennyson had studied at Cambridge under his tutor, the great philosopher of science William Whewell, who knew and supported the catastrophists, and who even coined their name.)

The catastrophists—Buckland, Sedgwick, Conybeare, and others—although not generally remembered today, were the geological giants of Tennyson's youth. They argued for a *nonevolutionary,* directional history based on successive creations of increasing excellence, separated by catastrophic episodes of extinction. Tennyson often cites them directly. Section 118 describes the origin of the earth by the nebular hypothesis (coalescence from rings of hot gases spun off from the sun), a central idea for catastrophists (as a starting point for life's progressive history, keyed to the earth's cooling), but denied by Lyell, who advocated a climatic steady state—"in tracts of fluent heat began," Tennyson writes. The famous lines about extinction ("from scarpèd cliff...all shall go") are descriptions of catastrophic episodes. Later in section 56, Tennyson even cites the favorite case-study of catastrophists, the Mesozoic "sea-monsters" (ichthyosaurs and plesiosaurs): "Dragons of the prime, / That tare each other in their slime."

In this light, we have no reason to regard Tennyson as an incipient evolutionist because he speaks so often about progress in life's history, for advance by successive creation was a hallmark of catastrophist geology. Tennyson may have been favorable to some form of evolutionary thinking—a subject widely discussed in the years before Darwin's *Origin.* He presumably imagined human spiritual progress as gradual and uninterrupted. But the biological and geological passages of *In Memoriam* record the progressivist catastrophism of his time, not the evolutionary theory of Darwin's world to come.

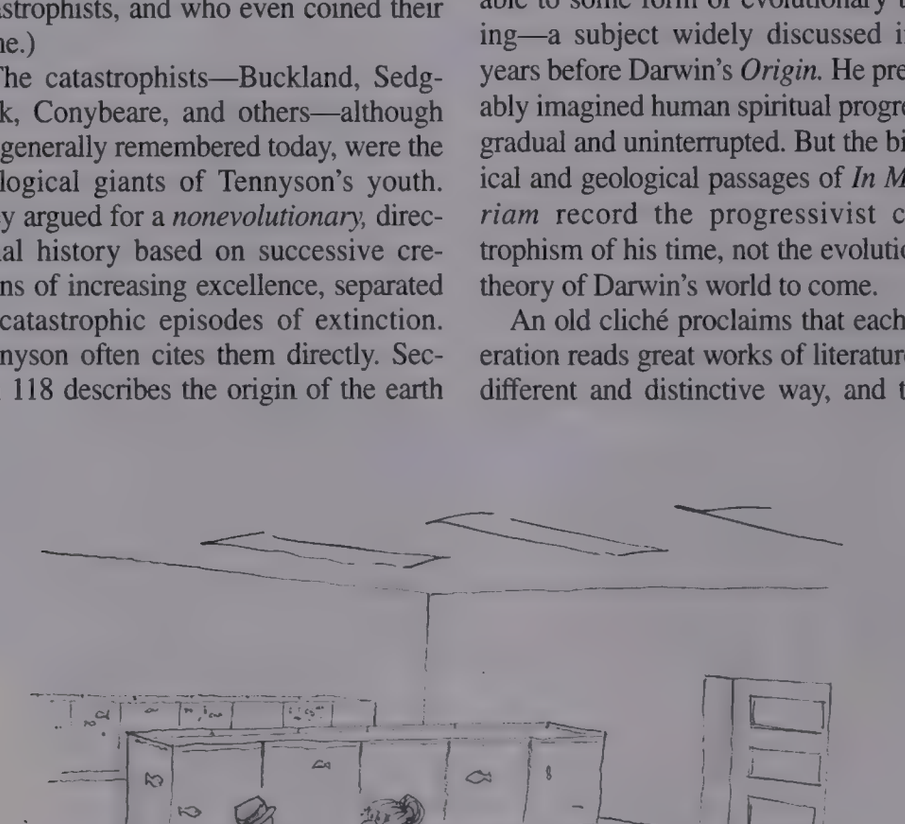
An old cliché proclaims that each generation reads great works of literature in a different and distinctive way, and that a primary sign of greatness lies in the intrinsic richness that permits so many changing interpretations. Tennyson's contemporaries read *In Memoriam* as a great religious poem, an odyssey in the rediscovery of faith, following deep grief and doubt born of a senseless and untimely death. The great liberal theologian Charles Kingsley, good friend of Huxley and author of *Water Babies* and *Westward Ho!,* wrote a major review of *In Memoriam* (*Fraser's Magazine,* September 1850). He called Tennyson a "willing and deliberate champion of vital Christianity," and labeled *In Memoriam* "the noblest Christian poem which England has produced for two centuries...[expressing] an orthodoxy the more sincere because it has worked upward through the abyss of doubt."

In his 1936 essay on *In Memoriam,* T. S. Eliot takes an almost opposite position. Tennyson, he says, "had the finest ear of any English poet since Milton." Eliot acknowledges the usual Victorian reading: "Tennyson's contemporaries...regarded it as a message of hope and reassurance to their rather fading Christian faith." But Eliot then demurs and supports the religious character of the poem from an inverted, modern perspective:

> *In Memoriam* can, I think, justly be called a religious poem, but for another reason than that which made it seem religious to his contemporaries. It is not religious because of the quality of its faith, but because of the quality of its doubt. Its faith is a poor thing, but its doubt is a very intense experience.... Tennyson seems to have reached the end of his spiritual development with *In Memoriam*; there followed no reconciliation, no resolution.

As a totally naïve reader, I experienced the poem differently again, and in an unoriginal manner that will probably be viewed as stereotypical for this generation. I find it hard to discern any consistent intellectual or philosophical answer to the key issue of Hallam's death and its meaning. The poem is full of contradictions and nonresolutions—as in Tennyson's shifting use of historical progress (dismissal as solace early in the poem; acceptance as subsidiary comfort at the end, when he views Hallam as a harbinger of higher stages).

I read the poem instead, and with an intensity that brought me to tears in places, as a wonderful and deeply truthful account of the psychology of mourning. You are devastated by an event that cannot be explained or reconciled: the love of your life is lost so young. Fundamentally, the primary thing you must do is wait—wait



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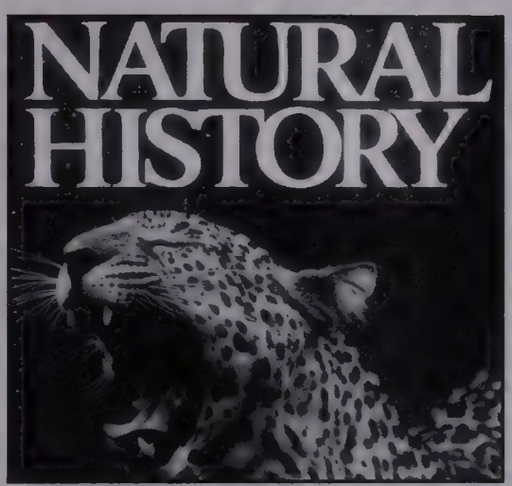

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while the long process of emotional healing, something deeply constitutional within us I suspect, plays out its long course of years. If you succeed, and do not sink permanently into despair, you eventually reconstruct your life. You find no answers, but you do accept because you must, and you move on. To me, *In Memoriam* is an odyssey in the working out of extended grief. I am awestruck all the more because Tennyson composed the verses in haphazard fashion over seventeen years, yet the sequence of 131 sections rings so true as a chronological account of grieving. How could Tennyson remember and capture the sequence so beautifully? How could he integrate the swirling and swinging moods: the anger, the despair, the emptiness, the search for answers, the exultation of temporary resolution ("Ring out, wild bells, to the wild sky" of section 106), the renewed despondency, the final acceptance without real answers?

Above all, I admire Tennyson's treatment of the relationship between science and human values—for I believe that his answer is entirely right, and just as important (if not more so) in our times. The narrator of *In Memoriam* probes several sources for answers to his quest for meaning—science prominently among them. He presents several characterizations of nature, some contradictory—red in tooth and claw, a domain of death for all species, a realm of steady progress through history. And he rejects them all as potential resolutions of his ethical and emotional quest.

On one obvious level, the narrator must reject science or any source of objective information—for how can any exterior knowledge extinguish the primal pain of personal grief? But Tennyson goes further and argues that, in principle, science cannot provide answers for moral questions about life's meaning. As a champion of science, not a detractor sniping from another profession, Tennyson lauds its power to build a global network of railroads, feed nations, answer empirical riddles of the universe—but he knows that science cannot tell us why a man should die so young or how a grieving lover should resolve his suffering.

Tennyson consistently held this position on the separateness of scientific and moral knowledge. He stated (as reported by his son whom, to add a footnote to the poignancy of this story, he named Hallam):

> We do not get this faith from Nature or the world. If we look at Nature alone, full of perfection and imperfection, she tells us that God is disease, murder and rapine. We get this faith from ourselves, from what is highest within us.

In Memoriam features the same sentiments. Early in the poem, in section 3, Tennyson considers and rejects nature as a source of moral instruction ("my natural good"):

> And shall I take a thing so blind,
> Embrace her as my natural good;
> Or crush her, like a vice of blood,
> Upon the threshold of the mind?

Later on, in section 120, he refutes the idea that our essence is nothing but our material self: "I think we are not wholly brain, / Magnetic mockeries." In a wonderful couplet, Tennyson allows that science might establish a material basis, but still would not speak to our moral struggles:

> Let Science prove we are, and then
> What matters Science unto men.

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ion does not guarantee an answer. I accept Tennyson's separation of scientific from moral and ethical quests; but few of us these days would be satisfied with Tennyson's particular answer, especially for resolving his grief at Hallam's death. Tennyson, by his own statements and all his friends' memories, was obsessed with the issue of personal identity for the soul after death. Following one of his few long talks with Tennyson, Huxley remarked that "immortality was the one dogma to which Tennyson was passionately devoted." And Tennyson himself stated: "The cardinal point of Christianity is the Life after Death." Thus, insofar as *In Memoriam* reaches a moral conclusion at all, Tennyson celebrates his voyage from religious doubt to confidence that he will meet Hallam again in heaven—a resolution that strikes most modern readers as lame after so much struggle.

My own dim life should teach me this,
That life shall live for evermore,
Else earth is darkness at the core,
And dust and ashes all that is.

Immortality, moreover, must be personal. The fusion of Hallam's soul into a glob of general good is not enough:

And I shall know him when we meet;
And we shall sit at endless feast,
Enjoying each the other's good.

But the particular character of Tennyson's personal solution doesn't vitiate the principle that answers to questions about ethical meaning cannot come from science. Tennyson, in fact, revered both sources and knew that "the good life"—a clichéd phrase perhaps, but do we not all seek it?—required their successful integration. Two separate sources; Huxley's world and Tennyson's. (Huxley, by the way, took the same position on the separate and equally necessary contributions of science and ethics to a reasoned life—see his famous essay *Evolution and Ethics*, often quoted in these columns.) Tennyson called these two sources knowledge and reverence, personified as mind and soul. And he spoke of their union with a metaphor from the discipline that owns "harmony" as a technical concept:

Let knowledge grow from more to more,
But more of reverence in us dwell;
That mind and soul, according well,
May make one music, as before.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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Rattling Round Beantown

by Richard F. Welch

Approximately ten miles south of Boston lies a rise of rocky ridges called the Blue Hills. Through a series of historical accidents, the Hills became the last remaining habitat within a hundred miles for a species that once ranged throughout Massachusetts and New Hampshire and possibly into Maine. The creature in question is the timber rattlesnake, *Crotalus horridus*.

LANDSCAPE WITH REPTILE: RATTLESNAKES IN AN URBAN WORLD, by Thomas Palmer. *Ticknor & Fields, $19.95; 340 pp.*

Although still plentiful in the Appalachians and the South, in the Northeast the species has suffered enormous losses in habitat and population. Thomas Palmer's *Landscape with Reptile* is an account of one relict population of timber rattlers, how it reached the reduced state in which it is now found, and perhaps more improbably, how it survives in its now urbanized and fragmented environment.

Palmer's approach is multifaceted, even discursive. At times the rattler disappears from the stage as the author recounts the history of how the Hills were set up first as a park for wealthy Bostonians and later as a nature preserve. In one chapter, Palmer digresses on the hermits and the homeless who have lived in the Blue Hills. Although the author skips around when it suits him, most of the work is historically oriented, beginning with the attitude of the local Indians—the Massachuset—toward the timber rattler.

Of course the great change in the rattler's situation came with the arrival of the Pilgrims and Puritans, whose Judeo-Christian horror of snakes led them to systematically exterminate the creatures wherever they were found. The fear of the rattlesnake was provoked and fanned by outrageously exaggerated stories of its alleged aggressiveness, ferocity, and toxicity. As late as 1937, a reputable herpetologist at the Staten Island Zoo—Carl Kauffeld—who certainly should have known better, wrote up a "killer snake" story about an incident in Windsor, Ontario, in May 1906:

The Blue Hills near Boston host a relict population of timber rattlesnakes.
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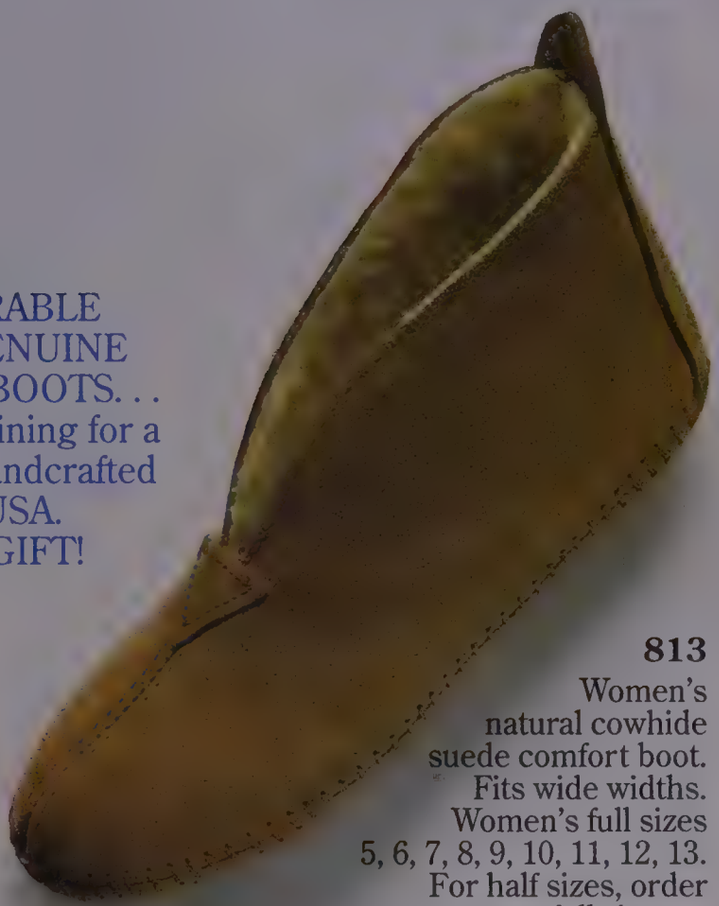

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At this time eight rattlesnakes and two pythons escaped from the Mount Clair clinic and within one week the rattlers caused the fatal poisoning of eleven people, one of the victims, a man, being bitten while he slept. For some inexplicable reason these snakes showed a strange preference for houses and office buildings, possibly because they had been in captivity for a long period and felt more at home under a roof than in their natural habitat out of doors.

Early settlers in the Boston area noted that northeastern rattlesnakes were fond of hills with rocky faces on which they could sun. The animals also frequented the same communal dens each winter, and these could be easily located. Typically, farmers sought out the animals as they emerged from their winter dens and beat them to death with poles and sticks. Despite the rattler's popular reputation for ferocity and aggression, there really wasn't much sport in it. By 1834, the timber rattler was extinct in most areas around Boston except for the Blue Hills, which had proved unsuitable for farming.

In the second half of the nineteenth century, after the reptiles had been driven to near extinction, amateur and professional scientists, from Henry David Thoreau to the members of the Boston Society of Natural History, began to view them less as an example of terror in the woods and more as an attractive and desirable part of the natural world. Modern environmental consciousness was born.

As Palmer makes clear, from the beginnings of European settlement into the nineteenth century, there were many who knew the truth about the timber rattler and even put their knowledge into print. The animal was retiring, and generally shy—especially around people. And while its bite was toxic, it seldom caused death. With one possible exception, Palmer can find no example in Massachusetts of a fatality due to the bite of a *Crotalus*.

Among the more intriguing sections of the book are those that deal with the attempts to find antidotes to rattlesnake venom. In the 1620s, Thomas Morton, a Boston area pioneer who provided one of the first generally accurate accounts of the snake, described how he saved his dog by pouring "salet" oil—probably olive oil—down its throat. Morton later reported the same result with a boy who had been bitten. Other cures included something called "snakeweed," which may have been obtained from the Indians.

Still later, the prescribed use of massive doses of alcohol, which increases heart rate, probably exacerbated the effects of the venom. According to Palmer, in 1908 5 percent of snakebite deaths were actually alcohol overdoses. Interestingly, the common method of making incisions on the bite to drain the venom and applying a tourniquet to keep the poison from traveling through the body was known by the middle of the nineteenth century. In 1927, a commercially prepared antivenin was produced.

Although the timber rattler's bite and toxicity have been exaggerated, the experience is no laughing matter. Snake venom probably evolved from digestive juices, and the site of a bite looks much like an area being converted into snakefood: tissues deteriorate, proteins and fats break down, blood vessels weaken, and red blood cells burst. This phenomenon is known as necrosis. If the effects are more generalized, repairs may become impossible, thus inviting bacterial attack and tissue loss. Serious tissue loss may even necessitate amputation of a limb. Usually, however, the effects of the bite will begin to reverse after two to three days, and there are no permanent aftereffects—except in memory. In rare cases, microscopic hemorrhages in the kidneys or lungs may cause death.

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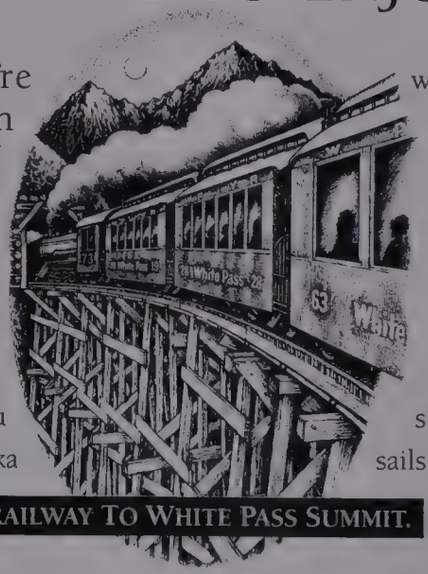

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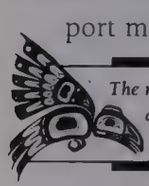

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ected (there is no venom injection in about one in four bites), and the size, age, and general health of the victim. Death is a highly unusual outcome; epidemiological studies estimate that the odds of dying after being bitten are about one in a thousand. According to Palmer's figures, in the United States each year there are about 5,000 cases of snakebite from venomous snakes—the various species of rattlers, plus cottonmouths and copperheads. Palmer does not mention coral snakes, and it is unclear whether they are included in this total.) Additionally, most of the bites are what Palmer describes as "illegitimate," resulting from attempts to capture, destroy, or molest the animals.

Where does this leave the timber rattler in the Blue Hills? Palmer gives figures of about fifty to sixty adults in the area now designated as a wildlife refuge. Unknown, but clearly small, numbers of the rattler's less venomous cousin, the copperhead, are also found in the Hills. *C. horridus* is now protected by the Massachusetts Endangered Species Act, which imposes a fine of $500 and a ninety-day jail term for a first offense.

Once the organized persecution ceased by the mid-1800s, the reptile might have been expected to recover its former numbers. Unfortunately, suburban sprawl and interstate highways consumed and chopped up its territory. Palmer describes how the snake became involved in a dispute over office and condominium developments, another example of conflicts between issues of environmental protection and economic development. This conflict heated up into a resounding political storm. Thanks to the real estate bust of the late eighties, however, the rattlers won out. But Palmer rightfully wonders what the result would be if another development project threatened the snake's habitat and population. Fifty or sixty adults are believed to be just enough to sustain a healthy population without genetic deterioration. Obviously anything that reduces this number threatens the small band of survivors.

Landscape with Reptile looks into the convoluted relationship between human beings and a generally unloved and underappreciated creature. In addition to biology, ecology, and even toxicology, Palmer touches on such topics as suburbanization, transportation, the rock quarry industry, the evolution of scientific thought, and even the philosophical origins of the environmental movement. The book does have some shortcomings, however. Aside from serendipitous observation, Palmer seems to have done no real fieldwork on the Blue Hills rattlesnake population, and little about their existence seems to come from his direct experience.

Additionally, he sometimes uses annoying "politically correct" or anachronistic terms and phrases. For example, Indians are "Americans" and white settlers are "Europeans." William Cullen Bryant is described as the first white person from New England to call a rattler "lovely," which implies the Indians did so too, although the author offers no evidence that this was the case. Palmer apparently buys the myth that the Indians possessed an innate love and understanding of nature beyond the capacity of most Caucasians.

Nevertheless, *Landscape with Reptile* is an intriguing examination of a human–wildlife relationship that will probably become increasingly common as the apparently inexorable pressures of human populations and demands overwhelm the natural world.

Richard F. Welch teaches history at Glen Cove High School and edits the Long Island Forum. *As a trustee of the Cold Spring Harbor Fish Hatchery and Aquarium, he pursues wide interests in natural history, especially herpetology.*

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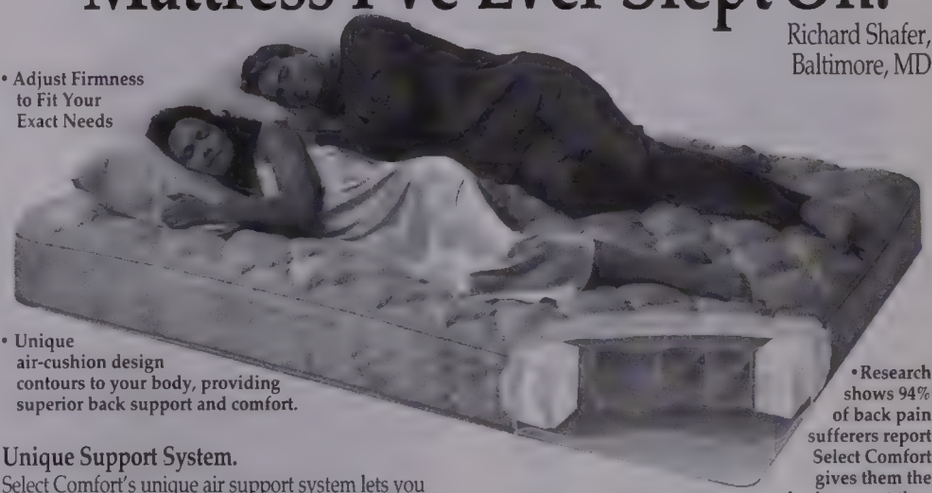

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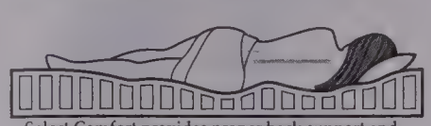

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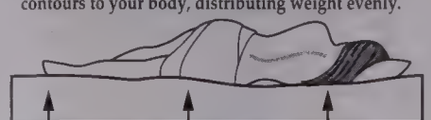

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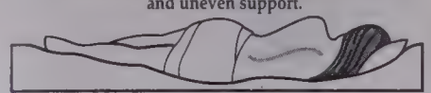

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Never having seen a live okapi, Sir Harry Johnston worked from skins and skulls to paint a watercolor of the animals in 1901. Their physical proportions are therefore not accurate.
Courtesy of J. B. Henderson

Between Sun and Shadow

The vast rain forests of the Congo Basin have hidden the elusive okapi for millennia

by Terese B. Hart and John A. Hart

The okapi was an animal of mystery even before it had been given a name or been seen by zoologists. At the turn of the century, the forests of central Africa, where this creature was thought to exist, had captured the imagination of Europeans. The accounts of early explorers and naturalists actually perpetuated the mystique. Herbert Lang, who led the American Museum of Natural History's Congo Expedition from 1909 to 1915, characterized the okapi's haunts as "an appalling wilderness." And in 1924, the naturalist-hunter Cuthbert Christy wrote of its "awe-inspiring grandeur."

Even before 1888, when he led the first expedition across the forests of what is now northeastern Zaire, Henry Morton Stanley surmised that this region held "the greatest marvels of Africa," including "strange mammals and birds." Later, in his book *In Darkest Africa,* Stanley reported that the Mbuti Pygmies knew of a donkey-like animal that "they sometimes catch in pits." As Stanley's own donkeys had died in the forest for lack of suitable forage, he further noted, "What they can find to eat is a wonder. They eat leaves."

More than a decade later, Sir Harry Johnston, special commissioner to Uganda, decided to follow up on Stanley's intriguing lead. In 1900, during an expedition to the eastern edge of the Congo forests, he was able to obtain some bits of striped skin from an animal known locally as *o'api.* At the London Zoological Society the skin was identified as belonging to a new species of horse. Less than a year later, however, when Johnston acquired two skulls and a complete skin of the animal, he realized it was not a horse but was related to the giraffe, and he tentatively identified it as a member of the extinct genus *Helladotherium.* Further study revealed that its greatest affinity was to the paleotragines, the most primitive group of fossil giraffes. This "living fossil" was given the name *Okapia johnstoni.*

It was years before Western naturalists would see an okapi in the wild, but they were impressed by freshly killed specimens brought in by native hunters. The okapi was indeed horselike in its dimensions, reaching more than five feet at the withers, with a shorter, thicker neck than that of the savanna giraffe. "The cheeks and jaws are yellowish white, contrasting abruptly with the dark-colored neck," wrote Johnston in the Smithsonian Institution's *Annual Report* of 1901. "The forehead is a deep red chestnut; the large, broad ears are of the same tint, fringed, however, with jet black. The neck, shoulders, barrel, and back range in tone from sepia and jet black to rich vinous red."

Herbert Lang was struck by the okapi's "delicately modeled deer-like head." In the *Zoological Society Bulletin* of May 1918, Lang wrote: "The glossy brown and purplish black of the body is set off by the conspicuous white stripes and bands on the limbs."

These sharply contrasting, zebralike markings break up the outline of the okapi's shape, creating an almost perfect camouflage in the light and shade of the forest understory. Despite its coloration and short neck, the okapi's rightful place within the giraffe family is affirmed by its skin-covered horns (only in males) and its bilobate canine teeth. The relationship is even more obvious when an okapi is feeding. Like its savanna relative, the okapi browses by twining its long, prehensile tongue around branches, stripping off the leaves, and pulling them into its mouth. It also uses it long tongue to groom all parts of its face.

The first okapi to be successfully exported alive went to the Antwerp Zoo in Belgium in 1919. But okapis were not widely available to zoos until the 1950s, when a capture station was established in the Ituri Forest, on the banks of the Epulu River. Okapis are still caught by traditional methods in deep, narrow pits in the forest around the Epulu Station, currently managed by the Institut Zairois pour la Conservation de la Nature. Local Mbuti Pygmies determine where pits should be dug and provide forage for the animals.

Although captive okapis have been studied in detail, little is known about the animal in the wild. In 1985, when we came to Epulu to begin the first field study of the species, mystery still clung to the okapi. Were okapis actually rare, as some zoologists surmised, or did their particular habits keep them out of sight? Okapis are not seen in groups with other large forest mammals at salt licks. They do not frequent open riverbanks and rarely forage at the borders of cultivated clearings. Even at close range, okapis disappear from view amid the tree columns and light flecks of their forest understory world.

Our study in the Ituri Forest has developed through a synthesis of the lore and skills of the traditional forest peoples with some of the most recent technology available to field biologists. From the beginning we have had the intimate collaboration of the Mbuti, who have led us with speed and assurance across large tracts of pathless forest and, with equal confidence, have inched us through the undergrowth to follow the fresh spoor of an okapi. Just as important has been the use of radiotelemetry, which has allowed us to track animals

that the forest conceals within its weave of sun and shadow.

With the help of local Mbuti guides and park guards from the Epulu Station, we selected a site in undisturbed forest on the banks of the Edoro River, twenty miles from the village of Epulu. We constructed a base camp, established an initial grid system of paths for radio tracking, and started digging and camouflaging pits like those used to capture okapis at the station—roughly eight feet deep, nine feet long, and three feet wide.

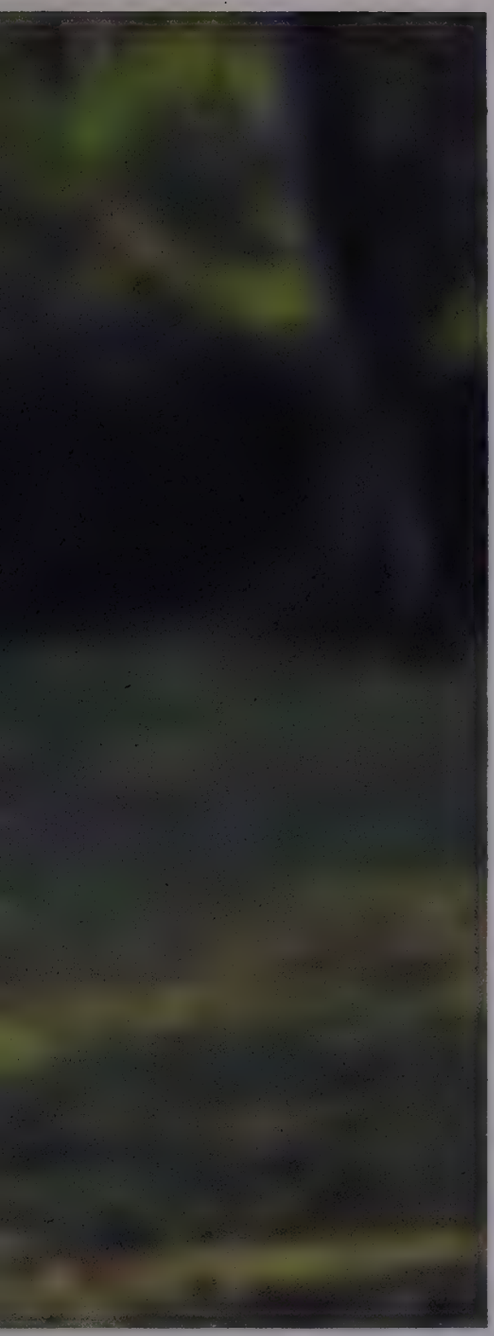
Our first animal was memorable, a young female christened Paskalina by our assistants for the Easter Day of her capture. Paskalina stood in the pit quietly as we leaned over and tried the collar first in one position and then another until we were satisfied that the radio transmitter, with its short wire antenna, was fastened securely but comfortably. We then filled the pit in front of her with earth until she was able to clamber up and out. She paused for a moment, looked back at us, then galloped off into the forest.

Paskalina initiated us into the skills and patience needed for our field study. Under the tutelage of our Mbuti guides, we learned to approach and observe Paskalina and other okapis, although there were frustrating times when we could hear but not see an okapi less than fifty feet away. In time we were able to teach a number of our assistants, including several Mbuti, how to use the portable receivers and hand-held antennas to locate and map the movements of collared okapis.

Our first discoveries came from watching okapis as they fed. Walking slowly, with the slight stiffness of a giraffe's parallel gait, an okapi moves through the shady understory sampling leaves from the right or left, sometimes stopping to strip more than one branch from an especially palatable shrub. Although the okapis were usually silent, we were most likely to hear one if it entered a small tree-fall opening. Here it often paused and browsed vigorously before moving on. For those few moments, the noise of bending branches and tearing leaves was audible at a distance of sixty feet or more.

Henry Morton Stanley's statement was correct: the okapi eats only leaves. Although okapis eat the youngest leaves, even these are generally as tough as oak or sugar maple leaves. There is very little grass in the forest, so grass is not an alternative. Nor do okapis feed on herbaceous monocots, such as those in the arrowroot and ginger families, that regularly grow in the forest openings and are important in the diets of chimpanzees and gorillas.

Yet diversity is the outstanding trait of the okapi's diet. Within the first year of our study, we identified well over one hundred species of broad-leaved plants that the animal eats; about twenty were particularly



Ric MacDowell

Naturalists first classified the okapi, left, as a species of horse, while Herbert Lang was struck by the okapi's "delicately modeled deer-like head." Lang returned from his expedition in 1915 without a live okapi, but he did bring back okapi skins and artifacts like the Azande hat, below.

Lynton Gardiner; AMNH

favored. We also observed that the okapi never eats one plant to the exclusion of others. Even where preferred foliage is sprouting in seemingly delectable abundance, an okapi will almost certainly leave much of it untasted, preferring to move on to sample other leaves. The okapi is an eclectic feeder but never a gourmand.

The okapi's forest is traversed by many other hoofed animals. No other animal, however, depends upon leaves in the shady forest understory to the extent that the okapi does. The forest duikers and chevrotains eat fallen fruits and seeds produced by canopy trees and lianas. Bongos, buffaloes, sitatungas, giant forest hogs, and elephants all feed on foliage, but these animals favor the vegetation growing in sunlit clearings, secondary forests, and swampy openings or along the edge of the forest where it meets the savanna. Even the pygmy antelope, the smallest of the forest ungulates and a strict leaf eater like the okapi, is restricted to openings in the forest. Because of its size (under five pounds), the antelope can meet its dietary needs within the circumscribed boundaries of small clearings.

Leaves in the forest penumbra are an expensive item. Light energy for leaf production is at a premium. "Shade" leaves tend to be fibrous, chemically well protected, and mostly unpalatable. Even insects avoid this foliage. Outbreaks of caterpillars, we noted, occurred in the sunny canopy, not in the light-deprived understory. The okapi's habits, thus, are exceptional. It keeps to the forest interior and avoids even the moist galleries and forest islands at the savanna edge. How else might this unusual feeding niche, we wondered, influence the okapi's behavior?

Over the four years following the capture of Paskalina, we have captured and collared more than twenty okapis. In following these animals, our path system has expanded to more than 180 miles in order to encompass their home ranges. This trail grid now covers twenty square miles (an area nearly the size of Manhattan), which we and our assistants patrol entirely on foot. Some of the okapis we caught were apparently merely passing through, disappearing out of radio range after a brief time in the area. During an aerial survey, we picked up the signals of several of our emigrating okapis more than ten miles beyond the perimeter of the study area. Fifteen okapis have remained resident for at least a year since their capture. Our longest record is for the female Bahati, whose name means "good luck" in Swahili. We were able to change her collar before its battery expired and have collected information on her for four consecutive years.

The most stable, although not the largest, home ranges belong to the reproductive females and vary between one and a half and two and a half square miles. Young animals of both sexes have more restricted ranges, overlapping at first with those of their mothers. Many, if not all, of these young eventually emigrate. Paskalina, for instance, disappeared nine months after we first caught her and was never found again despite extensive searches. Adult males cover larger areas, sometimes more than five square miles during the course of a single year, and their ranges overlap extensively with those of other bulls.

Adult females have exclusive use of their territory, except when they have young and when males make brief incursions for mating. Female okapis lack

With a tongue that can stretch to a length of eighteen inches, below, the okapi easily cleans its eyes and grooms its whole body. The animal is so well camouflaged, right, that it is almost impossible to detect in the shadowy forest understory. The traditional Mbuti method of trapping okapis alive in deep, narrow pits, below right, is still the most effective way to catch the animal.

Photographs by Geneviève Renson

horns, but they weigh upward of 600 pounds and are noticeably taller and more massive than the bulls. Both sexes mark trees and shrubs with a brown, oily secretion from their skin and tend to defecate in selected areas. This may aid in marking territories and in communicating their reproductive state.

Male courtship is unobtrusive and cautious. Twice we observed a male taking the better part of a day to approach a female, announcing his overtures with low, barely audible moaning calls from more than fifty feet away. One male does not appear to have exclusive control over a cow. We have seen Bahati associate with two different bulls over the course of several days by moving from one area of her range to another. Such use of space is unusual among ungulates. Even among the okapi's closest relative, the savanna giraffe, bulls are larger than cows and may attempt to control their movements and groupings.

The distribution of the okapi's food plants throughout the Ituri Forest favors dispersed rather than congregated foraging. We have observed okapis feeding in swamp forests, in the tall ironwood and mahogany forests of the rolling uplands, and in the short forests on rocky hilltops. Nowhere, however, is the okapi's forage abundant or dense enough to support a herd. Nor do okapis converge on seasonal food sources, because year-round warmth and rain promote continuous growth of new leaves. The plants that are the okapi's dietary staples in the Edoro study area—shrubs, lianas, and the saplings of large canopy trees—are widely, but unevenly, distributed throughout the Ituri. We discovered that the home ranges of breeding females have more of these plants than the home ranges of males and subadults. Thus, adult females occupy the areas of forest that are richest in food.

Once we were able to follow Bahati through her reproductive cycle, the function of female territoriality became evident. Over the course of her fourteen-month gestation period, Bahati's behavior did not change markedly. Once her calf was born, however, Bahati, who had previously spent a considerable portion of her day quietly resting, now began spending more time feeding. She moved back and forth across her range, often at some distance from the calf, which she left hidden and visited just a few times a day for only a few minutes each time. Although she ate more and more, her physical condition deteriorated. Another female that we caught during peak lactation was so thin that we worried she might not be able to climb out of the pit after we collared her.

During the lactation period, we found stripped and nipped stems everywhere on a mother's home range, whereas before the calving, signs of okapi browsing had been sparse. One calf that we were able to collar stayed with its mother for at least nine months. With mother and calf feeding on the same group of plants, these staples were almost depleted. Perhaps the only females to reproduce successfully are those that can claim the best home ranges with the greatest amounts of palatable leaves.

Unlike females, males are not restricted to areas where food is most abundant. Without the energy requirements of lactation, males can spend more time roaming in forest zones where palatable leaves are sparse. The males' more extensive roamings can be understood as an effort to gain access to as many females as possible.

Although we have begun to elucidate certain patterns in the overall picture of

John and Terese Hart

okapi biology, answers to some fundamental questions continue to elude us. Why, for instance, is the okapi everywhere a creature of forest shadows? Why doesn't it range out into the broad transition zone between forest and savanna, where many of its favorite plants abound?

Sir Harry Johnston, writing at the time he brought the Western world's attention to the okapi, proposed that in the course of evolution, the "defenseless" okapi retreated to the forest interior to avoid predators. Johnston discounted the leopard as a potential okapi predator in the forest, because he thought that the cat was arboreal and preyed mainly on primates. However, okapis are indeed vulnerable to leopard attacks. A number of both collared and uncollared animals in the Edoro study area have been killed by leopards during the course of our study. An alternative expla-

The okapi habitat group was created for the Akeley African Hall of the American Museum of Natural History in 1938. Herbert Lang collected the okapi in the background, and William D. Campbell collected those in the foreground in a 1937 expedition.
Arthur Singer; AMNH

nation for the okapi's restricted niche is that the animal has been "pushed" into the forest by competition with other large, hoofed animals—such as the bushbuck and bongo—that specialize on the forest edges and use them more efficiently.

Another observation for which we still have no ready explanation concerns the limited distribution of okapis in northeastern Zaire. The okapi's range does not correspond to the distribution of its preferred plants in the Ituri Forest. These same plants occur in areas where the okapi is absent. Okapis also flourish in the Maiko Forest, more than 125 miles southwest of our study area, on entirely different staples. Why don't okapis range throughout the entire central African forest zone?

Perhaps the history of the forest holds a clue to the answer. The okapi is not the only unusual animal endemic to the forest areas of northeastern Zaire. As Stanley predicted, there have been other remarkable discoveries. The American Museum expedition to the Congo came back with specimens of a strange fishing genet and the feather of a large, unidentified bird that was later recognized as the only African pheasant, the Congo peafowl. Are these species, along with the okapi, relicts of an earlier era when they were confined to islands of forest whose borders they continue to respect even though the forest has since expanded?

Whatever the case, today the okapi is thriving in Zaire's Ituri Forest. Its existence seems assured as long as the old-growth forest upon which it depends continues to exist. But the great forests of equatorial Africa are once again at risk of being reduced to islands, this time by the hands of humans through bush fire, agricultural immigration, and intensive hunting. Will this "surviving fossil" weather these new pressures? Like all the Ituri Forest's fauna and flora, the okapi's future depends upon the ability of the people of Zaire, with the participation of the international community, to stem the tide of destruction advancing on this still awe-inspiring forest. □

Triarthrus, *trilobites died hundreds of millions of years ago when fine mud suddenly blanketed their sea-floor home near what is now the outskirts of Rome, New York. Two fossilized graptolites lie between the trilobites.*
Thomas Whiteley

The Gold Bugs

For fossil prospectors, the treasure in a New York quarry was trilobites

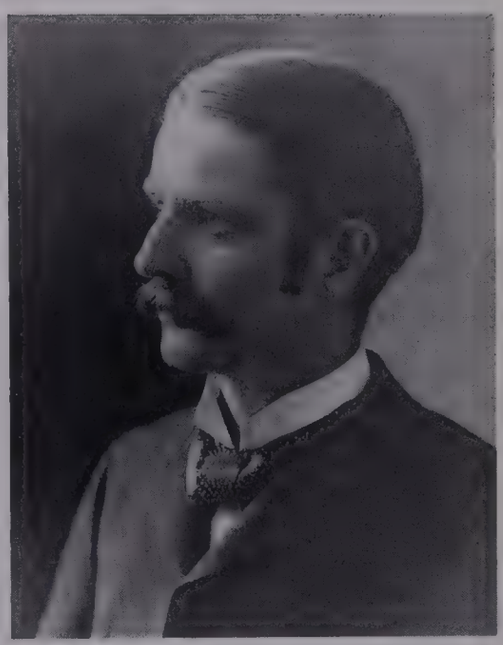
by Derek E. G. Briggs and Gregory D. Edgecombe

Some 450 million years ago, the rolling hills, river valleys, and woodlands of central New York State were submerged under an arm of a great sea. A variety of now-extinct creatures flourished in the cold 300- to 600-foot-deep waters and in the rich organic sediments of the dark sea floor. Most abundant were trilobites, members of the family of scuttling, many-legged invertebrates with crusty outer skeletons that thrived during much of the Paleozoic era. The inch-long trilobite *Triarthrus* scavenged organic debris from the sediment and captured worms and other soft, nonshelly prey. Using its spiny legs, it passed these morsels along its belly from back to front toward the mouth before devouring them, much as a horseshoe crab does today. Another kind of trilobite, known as *Cryptolithus,* was eyeless, but a fringe on its head may have allowed it to determine the direction of currents. *Cryptolithus* scratched out shallow burrows and fed on tiny creatures in the sediment on the sea floor. Trilobites shared the seabed with brachiopods, corals, starfish, crinoids (also known as sea lilies), and bryozoans (moss animals), while beneath them, clams occupied snug burrows in the mud and sand. In the water above were long, straight nautiloids and free-floating colonial graptolites, rafts of tubular skeletons that housed tiny, tentacled animals called zooids. When these swimmers and floaters died, they drifted to the bottom. Their soft remains sometimes became food for scavengers and their shells became islands to which brachiopods attached themselves. At other times, they settled undisturbed into the sediment.

This scene seems to have ended quickly. A sudden, massive influx of fine mud entombed the trilobites and the rest of the aquatic community. But by rapidly blanketing the animals, the mud also helped preserve their remains. Their fossils, found in a portion of the ancient sea known today as Beecher's Trilobite Bed, provide us with a snapshot of animals that lived on and above the sea floor some 450 million years ago.

In 1884, William S. Valiant, who later became assistant curator at Rutgers College, discovered some trilobite fossils along a creek near Rome, New York. In 1892, after repeated attempts, he located the level of the outcrop from which the trilobites had been dislodged. A lode of the fossils was embedded in a stratum of rock, known as the Frankfort Shale, that dates from late in the Ordovician, the epoch that lasted from about 510 to 439 million years ago. The fossils were a paleontological bonanza. They not only revealed the hard exoskeletons of the preserved creatures but also clearly delineated their soft parts, including the limbs, head appendages, gut, and muscles. These tissues, as well as the exoskeletons, had been filled or replaced by iron sulfide, the mineral pyrite also known as fool's gold. When cleaned, the pyrite-filled forms of the creatures shine against the black shale in which they lie embedded.

Pyrite, produced by sulfate-reducing bacteria, forms readily in fine-grained marine shales where oxygen is absent. Although it is usually scattered through the sediment, in rare cases pyrite concentrates around a carcass and results in the fossilization of soft tissues. Apart from this fossil bed, the only other prime example of soft-tissue pyritization is Germany's Hunsrück Slate. This Early Devonian rock, about 390 million years old, holds a fossilized community of animals, mainly sea lilies, starfish, and mollusks, but including trilobites and other arthropods, their bodies replicated in pyrite.



Paleontologist Charles Emerson Beecher
Peabody Museum of Natural History, Yale University

In 1893, Yale University paleontologist Charles Emerson Beecher took over the scientific study of New York's golden trilobites. Beecher, whose name was given to the bed yielding the fossils, carried out a massive quarrying operation. During the summer of 1893, he sent two tons of rock to Yale, but just two years later, the site was considered mined out. Beecher went on to publish many papers on trilobite limb structure and larval development and died in 1904 while drawing a trilobite from the Rome site.

After Beecher's death, the bulk of his material disappeared and the exact location of the bed was forgotten. In 1969, John Cisne, of Cornell University, tried to find the quarry along the creek. Although

Thomas Whitely

an overgrown section in the ravine near the creek matched Valiant's field photograph of the site, Cisne found no pyritized trilobites. But trilobite aficionados are a persistent breed, and the fossils are keenly sought by collectors. In 1984, two experienced collectors, Thomas Whiteley and Daniel Cooper, decided to relocate Beecher's Trilobite Bed to establish whether it had indeed been depleted. Using published accounts and maps, they managed to pinpoint a probable quarry and began to dig through a section of the Frankfort Shale. They found a 1.5-inch siltstone bed, which, upon being split, revealed pyritized *Triarthrus* at the predicted level. In 1989, paleontologists from the National Museum in Washington, D.C., and the American Museum of Natural History in New York jointly conducted an extensive excavation of the site, the first in this century. The project offered an opportunity to gather new material and to investigate how and why the remarkable pyritization had occurred. We joined the researchers at Beecher's Trilobite Bed in August 1989.

When we arrived at the site, the excavator and bulldozer had moved tons of shale. The trilobite bed was some four feet below the level of the now-open face of the valley. The beds of shale were thin, continuous, and nearly horizontal—an example of real layer-cake geology. The sequence of beds was cut by straight vertical cracks that crisscrossed the quarry at irregular intervals, as if the cake had been cut. The two of us and ten colleagues did much of the fine excavation by hand. Although the layer we were after is a mere one and a half inches thick, it does not split easily. The trilobites have to be prepared for study in the laboratory. Occasionally, during the field excavation we had tantalizing glimpses of parts of a *Triarthrus* when the heavy siltstone bed fractured, but the most striking fossils we saw were a few straight nautiloids more than two feet long that emerged as the rock above the trilobite bed was broken up and removed.

We needed to take samples not just of the trilobite bed but also of the shales above and below it. Blocks about four feet thick were extracted using hammer and prise bars, and sections of these slabs were sent to Leeds, England. Chemical analyses showed that the sulfur isotopes in the pyrite changed at various levels in the rock sequence. A major change in the values at the level of the trilobite bed indicates a sudden geological catastrophe.

Fossils of soft body parts, like those found in Beecher's Trilobite Bed, are not simply preservational curiosities. They provide a rare and invaluable record of ancient life. Most of the fossil record consists of teeth, shells, and bones and is primarily a view of those creatures with parts that resisted decay. Much of our understanding of patterns of diversification and extinction, for example, is based on the shells of

Filled with pyrite, or fool's gold, the delicate paired legs and antennae of a Triarthrus *trilobite, left, are unusually well displayed. Scanning electron micrographs of* Cryptolithus tesselatus, *similar in development to Beecher's Bed* Cryptolithus, *illustrate the trilobite's growth stages. The sand-grain-sized young larva, right, characterized by a bulbous shield, floated freely in the sea. The larva then underwent a metamorphosis, below, growing body segments, spines on the head shield, and a head fringe. Such juveniles were ready to take up life as bottom dwellers. A later stage, bottom, is peppercorn size and reveals additional body segments and rows of sensory pits on the head shield.*

Brian D. E. Chatterton

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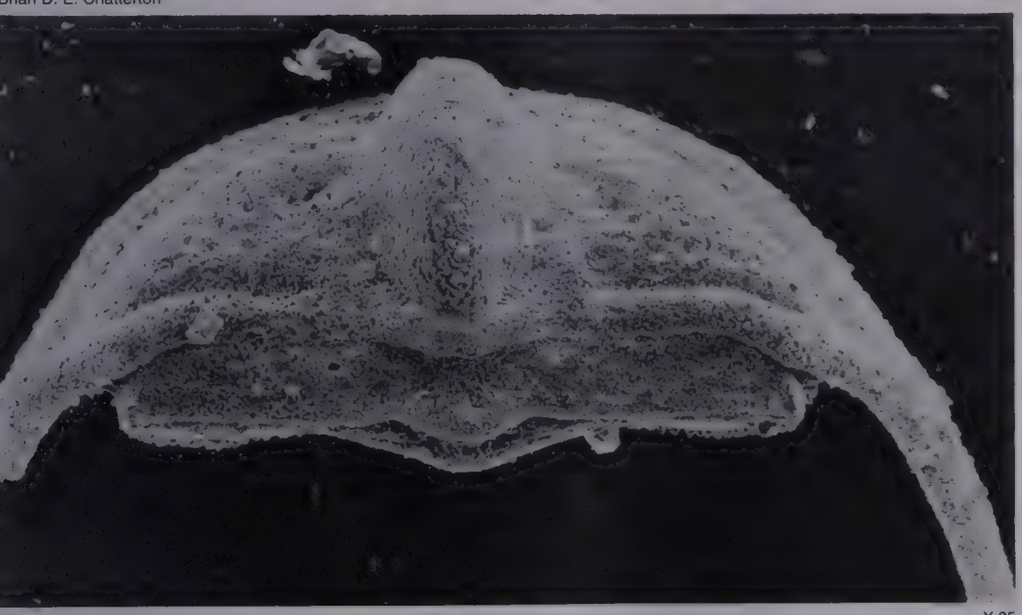

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X 40

shallow marine animals. Without the occasional preservation of soft parts—including muscles, limbs, antennae, stomachs, and even remnants of meals—many of the unusual animals of the early Paleozoic that lacked hard shells would be completely unknown.

In rocks of certain ages and in certain environments, soft-bodied fossils are relatively common. The rocks of the Burgess Shale in British Columbia, Canada, of Cambrian age, some 560 to 520 million years old, are renowned for a diversity of soft-bodied fauna (see *Natural History,* December 1985, January and February 1986). Pyrite, however, is a rare feature of the Burgess Shale fossils, which are covered by a film of a complex alumino-silicate mineral similar to mica. Other rocks of similar age from localities as far apart as Pennsylvania, Greenland, China, and Australia have also afforded a look at the array of creatures, both shelly and soft, that inhabited the earth during the Cambrian. But among more than sixty major examples of soft-bodied-fossil preservation, the only significant example known from the Ordovician is Beecher's Trilobite Bed.

Toward the end of the Cambrian period, many life forms went extinct. Trilobites were hit particularly hard, and many vanished. A number of families, however, squeezed through and gave rise in the Ordovician to new and diverse groups, including trilobites more specialized for certain ways of life than were their generalist Cambrian ancestors. Some developed enormous eyes; others, such as *Cryptolithus,* became blind but evolved a sensitive pitted fringe around the head shield. Some were covered with extraordinary spines, while others were smooth and flattened. Equipped for varied life styles, these trilobites became members of specialized new communites that colonized the sea water, the sea floor, and the underlying sediment.

Because of the depth and cold temperature of the water, the diversity of life in Beecher's Trilobite Bed is not so great as in the Burgess Shale. Still, about thirty dif-

ferent animals are known. The pyritization of the fossils has given us insights into the way the animals lived. Because pyrite is opaque to X-rays, the fossils can be studied within the rock. Two X-rays taken from different angles can be used in combination to produce a three-dimensional stereoscopic image of the animal. In the early 1970s, John Cisne conducted detailed X-ray studies on available remnants of Beecher's original trilobite material. His work revealed important new anatomical information about *Triarthrus,* the most abundant inhabitant of the bed, including the first traces of trilobite muscle.

At Cambridge University, trilobite specialists Harry Whittington and John Almond studied the legs of *Triarthrus,* which have inward-facing spines, and reconstructed the way that it might have walked—with the right and left limbs of each pair in phase, moving in concert like those of a millipede. *Triarthrus* did not undulate as do faster-running centipedes, which move the right and left limbs out of phase. The spines along the inner margins of its legs probably helped *Triarthrus* to capture small prey animals, which were shunted from leg to leg along the belly to the mouth. In addition to actively hunting—for example, uprooting worms from the sea-floor sediment—*Triarthrus* may also have scavenged remains of dead animals. On the outer branch of the limbs, *Triarthrus* had numerous long, parallel filaments that may have been used for oxygen exchange in the manner of a gill.

The blind trilobite *Cryptolithus* is characterized by a remarkable fringe around the margin of the head shield. This head shield tapered backward into two long, lateral spines that helped support the animal as it rested or fed in the sediment on the sea floor. The fringe itself is covered with regularly spaced pits, which may have compensated for the lack of eyes by enabling *Cryptolithus* to detect the depth of the shallow excavations it made or to monitor currents and thus stabilize itself on the sea floor.

Other inhabitants of the beds that have been studied in their pyritized fossil form include *Climacograptus,* the floating colonial graptolite, the most abundant of the animals that occupied the sea water. The fossils look like tiny double-edged, serrated swords, the "sawteeth" being the remains of the now-flattened tubes in which the individual zooids lived, filtering particles of microplankton from the water with their "tentacles."

Like other arthropods, such as insects and crustaceans, trilobites had a rigid exoskeleton and grew by molting in stages, or instars, at periodic intervals throughout their lives. Thus, as it grew, each individual trilobite left a series of molted outer "skins," or exoskeletal remains, that have in many cases been preserved. These molts are hard and calcitic but rarely pyritized because in contrast to carcasses, they lack soft tissue for sulfate-reducing bacteria to break down.

Given a collection of molts of varying intermediate size, paleontologists can often match up larval and juvenile trilobites with the corresponding adult. This process is easier for those trilobites that changed gradually with increasing size, but difficult with those that metamorphosed radically between the earliest larval stage and subsequent stages. Beecher's Trilobite Bed has yielded numerous baby trilobites that exemplify both of these life histories.

By carefully poring over what was left of Beecher's original material, John Cisne discovered the molts of many trilobite larvae. He demonstrated that the number of individual trilobites decreased logarithmically with each increase in size. They follow the pattern one would expect if catastrophic burial preserved a population of *Triarthrus* frozen in time, killing large numbers of larvae and juveniles but fewer adults. (In contrast, when fossils of animals that have died and accumulated over

Germany's 390-million-year-old Hunsrück Slate rivals Beecher's Trilobite Bed in the quality of its pyritized fossils. The Hunsrück invertebrate community was graced by sea lilies, left, and starfish, below, shown in X-ray.
W. Sturmer; Forschungsinstitut Senckenberg, Frankfurt; Catalog nos. 34 and 45

a long period are found together, they show a much less regular pattern of size distribution.)

The smallest larval trilobites found in Beecher's Trilobite Bed are not baby *Triarthrus,* but larvae of a completely different kind of trilobite known as *Cornuproetus*. Although abundant in the bed as larvae, it is rare in its adult form. In contrast, *Triarthrus* was dominant among the adult trilobites but unknown in the bed in its earliest larval form. The youngest larvae of both *Triarthrus* and *Cornuproetus* must have been physically and ecologically separated from advanced juveniles and adults, feeding in different ways and occupying different habitats. Adult *Triarthrus* and baby *Cornuproetus* lived on the sediment and both were overwhelmed by the influx of mud that buried and preserved them. Adult *Cornuproetus* and the youngest stages of *Triarthrus* were not buried and must have lived elsewhere. Perhaps they sought shallow areas closer to shore.

Ecological separation of larval and adult trilobites is even more striking in *Cryptolithus,* the blind trilobite and the second most common in Beecher's bed. In its very young larval stage, *Cryptolithus* is globular, with a "crown of thorns" made up of an array of downward-projecting spines. These spines leave little room for movement of limbs, indicating that the larvae drifted with the plankton on the ancient sea. Because no intermediate steps have come to light in the detailed fossil record of the bed, we believe that *Cryptolithus* larvae metamorphosed in one step into adultlike juveniles. This sudden, radical change in form probably corresponded to a shift in the trilobite's ecology; like many decapods (for example, lobsters and crabs) in modern seas, it went from the planktonic, seaborne life of a larva to the bottom-dwelling, crawling life of an adult.

The life histories of the Beecher's Bed trilobites helped determine how long these animals would continue to populate the world's oceans. Paleontologists Brian Chatterton, of the University of Alberta, and Stephen Speyer, of Arizona State University, have demonstrated that trilobites that metamorphosed from planktonic larvae to bottom-dwelling adults were much more likely to have become extinct by the end of the Ordovician than were trilobites without a metamorphosis in the life cycle. One of the largest marine extinctions, the Ashgill event of 440 million years ago, wiped out all trinucleids, the family to which *Cryptolithus* belonged. While we are not certain of its cause, we have some clues. This worldwide event seems to have coincided with a major fall in sea level, glaciation of the Southern Hemisphere, and changes in water temperatures. Being especially vulnerable to fluctations in sea temperatures, *Cryptolithus* and other creatures characterized by a planktonic life stage died out.

Life history, however, is not the only factor that influenced trilobite survival.

A. Graffham; Visuals Unlimited

A reconstruction of a shallow-water Ordovician scene, below, depicts a giant nautiloid, trilobites, and other invertebrates, whose deep-water counterparts inhabited the sea floor that became Beecher's Trilobite Bed. Right: The trilobite line lasted 320 million years and included species large and small, smooth and spiny, giant-eyed and blind. A 380-million-year-old specimen of the robust trilobite Greenops boothi *is in a rolled-up, defensive posture; the spines at the edge of its tail shield project forward from beneath the head.*

AMNH

Triarthrus is a member of the olenids, a family of trilobites that thrived in poorly oxygenated, deep marine basins in the late Cambrian and early Ordovician and whose fossils today are found in the black shales typical of such an environment. While Cambrian sea level changes drastically affected trilobite families that lived in shallow shelf areas, olenids and other animals adapted to the tough life in deep basins were largely unaffected. Even among the hardy olenids, *Triarthrus* was a notable survivor. It became the longest-lived member of its line, carrying on within its quiet backwater and extending the range of its family to the end of the Ordovician. A biologist transported back in time to the Ordovician seabed near Rome, New York, would have regarded *Triarthrus* as a "living fossil" even then.

What ultimately caused the extinction of *Triarthrus*? Levels of oxygen available in the trilobite's last haunts may have been crucial. At the end of the Ordovician, the glacial icecaps melted and sea level rose. The muddy sea bottoms favored by olenid trilobites, the family including *Triarthrus,* became even deeper. Oxygen may have become scarce or been eliminated over large areas of the world's now deeper oceans. With a complete lack of oxygen, even the well-adapted *Triarthrus* would have died out. The last known species of *Triarthrus,* however, lived in a singie basin in southern Ontario. Here local uplift of the land may have increased erosion and propelled great amounts of sediment into the sea. This would have increased the amount of oxygen available and reduced the concentration of rich organic matter, effectively wiping out the habitat of the last *Triarthrus.*

Even after the extinction of *Triarthrus,* other kinds of trilobites lived on. The trilobite line stretches from the Cambrian, along more than 300 million years of evolution, extinctions, and radiations, to the late Permian period, about 250 million years ago. Beecher's Trilobite Bed offers us a slice of life, a window on the long life and sudden death of a few members of this remarkable lineage. □

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The Bottom of the Bottom of the World

Braving the Southern Ocean's frigid waters, a diver finds unexpected diversity on the sea floor.

by David G. Campbell

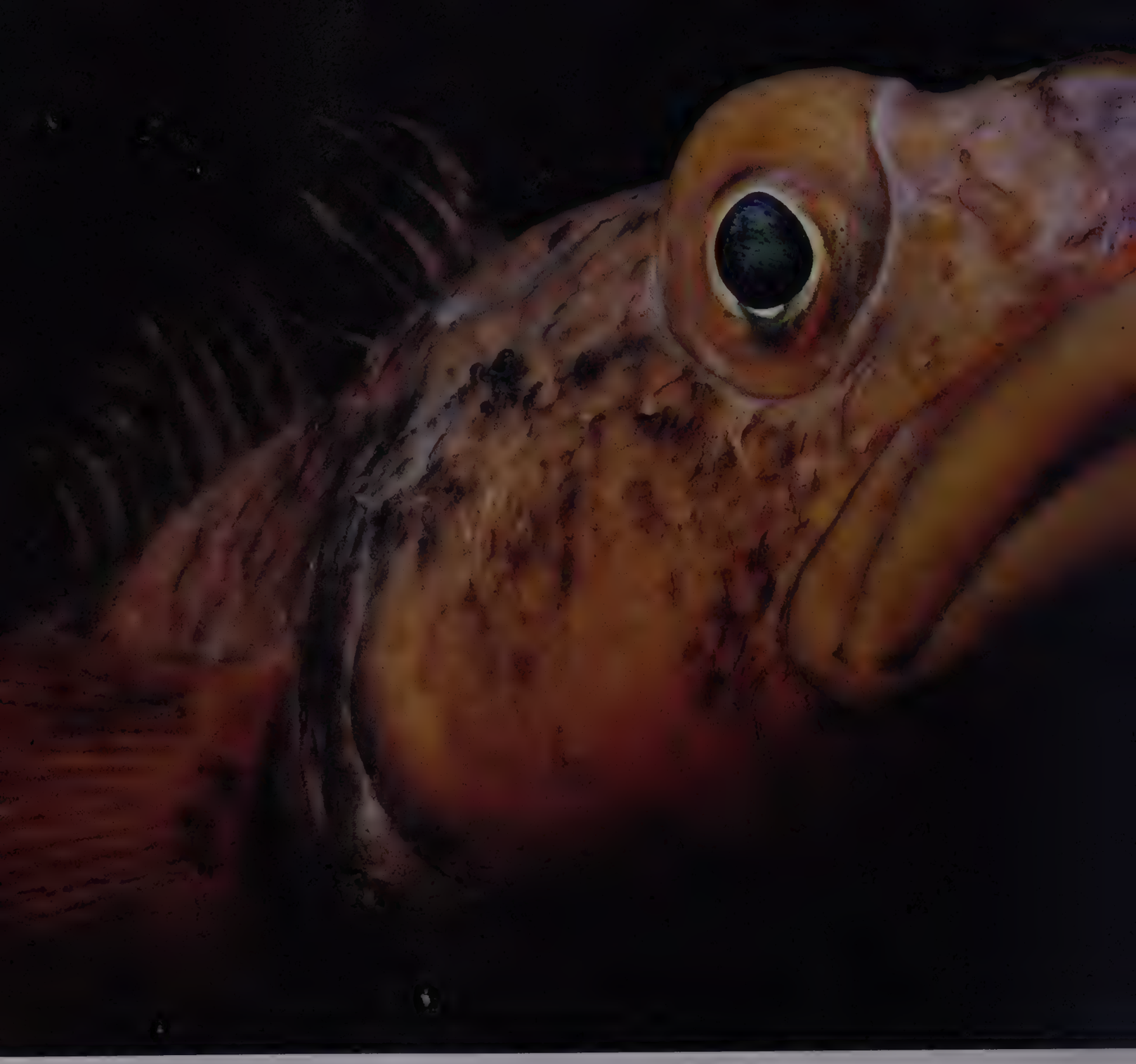
> Roll on, thou deep and dark blue
> Ocean—roll!
> Ten thousand fleets sweep over
> thee in vain;
> Man marks the earth with ruin—
> his control
> Stops with the shore.
>
> —*Lord Byron*

It was snow-hailing the morning I made my first scuba dive into the Southern Ocean, the freezing sea that surrounds Antarctica. The water temperature was 33° F, so cold that an unprotected diver would lose consciousness and die after only a few minutes' exposure. I donned several layers of woolen underwear and socks, a one-piece neoprene dry suit, a hood, booties, and three-fingered mittens. Only a few dozen people had previously gone into this realm. Until the late 1950s, when humans first began scuba diving in antarctic waters, this sea floor was beyond the reach—and the ken—of science. During the austral summer of 1987, I had the opportunity to enter this cold and dark sea. I was invited to Comandante Ferraz, the Brazilian research station at the edge of Admiralty Bay, a three-fingered fiord on King George Island, sixty miles off of the Antarctic Peninsula. There my Brazilian colleague Renato Garcia and I were researching the parasites of marine invertebrates and fish.

The dive was made from the beach, following a transect line to a buoy anchored 300 feet off shore. On this still January morning, the underwater visibility was sixty to ninety feet. Near the shore, icebergs had plowed furrows in the soft bottom and dropped boulders, worn smooth by their long, grinding passage. Some boulders were covered with a fur of brown diatoms and green filamentous algae, while others were scraped clean. Most of the rocks had one or two antarctic limpets grazing on them.

Adapted from *The Crystal Desert: Summers in Antarctica*, by David G. Campbell. Published by Houghton Mifflin Co. © 1992 by David G. Campbell.

Even though sea spiders are mostly legs surrounding a diminutive body, they are slow moving and awkward.
Bill Curtsinger



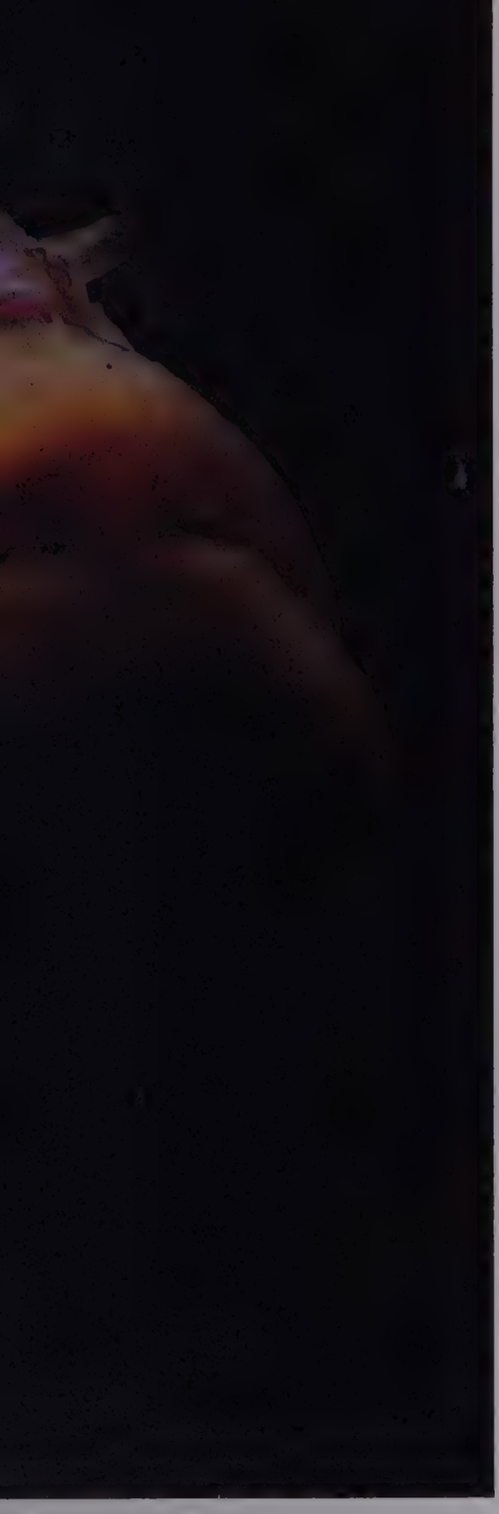
Amphipods—small, shrimplike crustaceans abundant in the Southern Ocean—were feeding on the algal beds and scurried beneath a rock. There are thirty-three species of amphipods in Admiralty Bay alone. Most are necrophagous—eaters of dead bodies—a common niche in lightless, deep antarctic waters where there is no primary productivity, but there is a gentle rain of organic material from the sunlit waters above.

Releasing a few bubbles of air from my suit, I eased down the undulating mud slope to a depth of thirty-three feet. At this depth, the antarctic continental shelf changed its appearance. The soft bottom gradually lost its ice scars and became a plain etched by the tracks of foraging animals. The deepest furrows were made by sea urchins. Covered with short, soft spines, the urchins looked like calcium mice. Although their spines seemed to be rising and rotating in confusion, they all were connected to a simple nervous system that pushed each urchin through the edible mud like a bulldozer.

Brittle stars, long-legged relatives of the urchins, also pressed their mouths to the mud, searching for buried clams. In some areas they were so abundant that they piled up on top of one another. They pulled themselves over the sea floor in short spasms, stamping partial rosettes in the mud; there were thousands of these images. A few of the brittle stars stood on their tapered leg-tips, a common behavior for which there is no obvious explanation. Fish hid in the cupolas formed by the brittle stars' legs. In an abyssal plain where every feature is rapidly smothered by mud and where there are almost no hiding places, the fish make do with what shelter they can find.

I swam to a depth of forty-five feet in the gloomy plain, beyond the reach of even the heaviest winter pack ice. Unlike the shallower sea, this was a realm of relative stability, remaining at a nearly constant temperature and receiving a steady rain of silt and nutrients from above. Here nemerteans—yard-long, wormlike organisms—lay on the surface of the mud. Each was striated by hundreds of annulations, the tracings of the muscles that push it peristaltically through the ooze. A wad of nemerteans, the size of a basketball, congregated in a prolonged communal copu-

Bill Curtsinger



A bottom-dweller in the shallow margins of Admiralty Bay, a notothenid fish, left, must avoid contact with fragments of floating ice, which could pierce it like a spear. Below: The head of an ice fish makes up one-third of the animal's total length; its toothed lips are well adapted for catching small fish and for plucking invertebrates from the sea floor.

David G. Campbell

lation. Nemerteans are gregarious at the supper table as well. Hundreds of them will gather atop a dead seal or other carrion on this sterile plain.

At these depths the ooze was alive with *Serolis polita,* a flat, thumbnail-sized isopod. The females were swollen with bright pink eggs, and when they swam, their legs beating in tandem like oars, they looked like flower petals in the dark water. Their segmented carapace, arched legs, and bilobed compound eyes, each mounted on a high turret, gave them the appearance of extinct trilobites.

Serolis is typical of antarctic marine invertebrates, including mollusks, polychaete worms, annelid worms, and sea stars, most of which produce a relatively small number of large, yolky eggs and nurture them to an advanced state of maturity before releasing them into the environment. In a realm where food is limited, this adaptation economizes on energy. The planktonic strategy of casting spawn to the currents won't do for the sea floor of Antarctica. Even the antarctic sponges tend either to be viviparous or to have some other form of brood protection. The brooding of eggs and larvae and the scarcity of island steppingstones in the Southern Ocean have for millennia isolated the antarctic shallow-water marine invertebrates from the rest of the world and have led to high levels of endemic species. Ninety percent of the amphipods and sea spiders, 77 percent of the sea urchins, and 66 percent of the isopods are restricted to these waters.

Thirty minutes after entering the water, I arrived at the farthest point of my dive, a ridge of rock that rose from the floor of Admiralty Bay. Unlike the unconsolidated silt, this rock was valuable real estate festooned with living things. Fixed organisms such as tunicates, soft and hard corals, and mosslike bryozoans projected their siphons, mouths, and tentacles into the nutritious water and in turn provided habitat for all manner of invertebrates and fish. At this depth, the full color spectrum of sunlight was filtered by the water and ice above, and the sea floor appeared gray and gloomy. But when I turned on my light, the beam was like a paint brush: everywhere I swept it was splashed with color. The anemones were orange, four inches in diameter, and consisted of a mouth (which doubled as an anus) fringed by tentacles. The drooping soft corals, which looked like long catkins, extended into the water and were bright yellow. Each coral colony consisted of thousands of tentacled polyps embedded in a flexible protein matrix. Each polyp, although only a fraction of an inch wide, was morphologically identical to that of an anemone. And like an anemone, each presented its mouth to the sea.

There were even a few foliating red and green algae at this depth, and aquatic lichens that colored the rock face a deep purple. Some of the rock itself was yellow calcareous algae, which extracts calcium that is dissolved in the sea and combines it with carbon dioxide to form calcium carbonate. These plants barely survive here. They scavenge light from the sea, just as

The four-inch-long giant isopod Glyptonotus antarcticus, *below, crawls over a rocky outcrop festooned with edible algae, bryozoans, and corals. A sea anenome, right, alarmed by a passing diver, withdraws its tentacles into the muscular tube of its body.*

Photographs by Bill Curtsinger

the animals with which they share this rock scavenge the rain of organic material.

Red sea urchins browsed on the algae, which they prised from the rocks with a rosette of spiny teeth. Bristled polychaete worms insinuated themselves in this living terrain, and sometimes entered the siphons of sponges and tunicates. They grazed upon the bryozoans and corals, munching the tissues of the very hosts that sheltered them. Frilled nudibranchs (snails lacking a shell) scraped algae off rocks and fed on the polyps of anemones and corals.

Glyptonotus antarcticus, a giant antarctic isopod four inches long, walked through the rock garden on six pairs of legs. Segmented, its shell dorsally keeled with flared margins, it looked as if it had been chiseled from stone. Isopods of this size are most unusual in shallow waters but are abundant in the limiting conditions of the abyssal depths of the world where, as on the antarctic continental shelf, slow growth to a large size is a common adaptation to the scarcity of nutrients.

Another giant, an eight-legged sea spider in the class Pycnogonida, was standing on its pointed legs in the ooze at the base of the promontory. Its rust-colored skin was crinkled by colonies of hundreds of bryozoans. The pycnogonid seemed to be all legs, moving hesitantly on its tiptoes. These animals are not built for the chase, but neither are their sedentary prey—sponges, corals, and bryozoans. They have a proboscis so massive and complex, relative to the minuscule body, that it is endowed with its own ganglion of nerves, in effect, a secondary brain. Many species use the proboscis to suck the tissues and fluids of their prey in a prolonged lethal kiss, and some have paired fangs, called chelicerae, which are used to prise off tissue and pass it to the mouth.

This formidable animal, as big as my palm, is another example of gigantism in the Southern Ocean. Most pycnogonids are minute, smaller than a fingernail, and although common throughout the world's seas, are seldom noticed. The sea surrounding Antarctica is inhabited by approximately 100 species of pycnogonid, several of which are giants.

The sponges on this promontory were mostly white and tan, a few were dirty yellow. Some were encrusted and adopted the shape of the rock on which they were growing. Their smooth surfaces were pocked with the incurrent and excurrent siphons through which they filtered plankton and organic material from the sea water. Others stood freely, cupping the water and catching the nutrients that rained from above.

Sponges are colonies of cells that are barely consolidated as organisms; they have no discrete organs, and the division of labor among their cells is rudimentary. Yet this lack of cell specialization endows the sponges with great powers of regeneration. One can mash the tissues of a sponge through a coarse cloth, and the resulting inchoate broth of cells will reassemble into an entirely new organism. Like the soft corals, the sponges have flexible internal skeletons made of interlocking pieces called spicules. In shallow tropical waters, most sponges have spicules that are made of flexible protein, but in the deep sea and on the antarctic continental shelf, the dominant group are the glass sponges, which have spicules made of brittle silicon, like the diatoms on which they feed.

The tunicates, nacreous and as pale as a dead man's fingers, also seemed part of the fabric of the rock. As adults, they have the

general appearance of sponges, with a tough protein and cellulose outer tunic (after which they are named) and single incurrent and excurrent siphons through which they filter the water. But a cosmos of evolution separates them from the sponges. They have a gut, a nervous system, and a circulatory system, complete with a heart. More remarkable, tunicates have larvae that resemble tadpoles, complete with a dorsal nerve cord and a rudimentary backbone called a notochord. This trait places them in the Vertebrata, the same subphylum as fishes, amphibians, reptiles, birds, mammals, and humans.

Serolis and its giant isopod relatives, the giant sea spiders, as well as the glass sponges so conspicuous and abundant in the shallow fringes of Admiralty Bay, are usually characteristic not of the shallow sea but of the deep benthos, the abyssal plains miles beneath the surface of the sea. In terms of the fauna, it was almost as if I were diving in the Mariana Trench, viewing scenes through the foot-thick porthole of a deep-diving submersible. Zoologists have long recognized the phenomenon of certain deep-sea invertebrates appearing in the shallows of polar seas.

The explanation can be found 100 miles offshore, where warm, deep water from the South Atlantic encounters the antarctic continental shelf. There it upwells, spewing nutrients into the shelf and, each spring, fostering a bloom of phytoplankton. This upwelling, which is rich in life, is known as the Antarctic Divergence. Part of the Divergence heads north, creating a huge vertical gyre; the water that heads south from the Divergence collides with Antarctica, eventually sinking and joining the deepest layer of all, the north-flowing antarctic bottom water.

The bottom water is born of ice. When sea ice forms, salt is concentrated in channels that slowly work their way to the bottom of the floe and are extruded into the sea. The water under the floe is therefore near freezing and high in salinity, conditions that make it dense. The antarctic bottom water slithers far north, over the edge of the continental shelf and into the abyssal zones at the bottom of the oceans. It oozes beneath the tropical seas, crosses the equator, and insinuates itself into the deepest areas of the North Atlantic and North Pacific oceans, a journey that takes decades, or even hundreds of years. All the while, its temperature remains near freezing. The abyssal areas of the world's oceans are consequently remarkably uniform: dark, salty, and cold. And as a result, the life forms that are found there are remarkably similar to the animals that live in the shallow seas surrounding the antarctic continent.

During my dive, I couldn't count the hundreds of species of invertebrates on the rocky outcrop and muddy plain. Taxonomists have identified 129 species of tunicates in the Antarctic, 875 species of mollusks, 650 polychaetes, 470 amphipods, 310 bryozoans, 299 isopods, and 100 pycnogonids. There are probably as many more yet undiscovered. But the proliferation of sponges may be the most surprising of all. More than 300 species have been identified in antarctic waters. Indeed, Antarctica today may have the greatest diversity of sponges of any place at any time in the earth's history, more even than the Paleozoic seas before the appearance of the vertebrates.

I could visit these depths for only a few minutes before the leaky suit and the cold set me shivering. Back at the station, I stood in a hot shower for half an hour and ate two plates of black beans and rice. Later in the afternoon, I returned to the bay to collect fish, which are the other hosts of the parasites that Renato and I were studying. We sailed a *Zodiac* through a fibrous slush of ice to pull in the fifty-foot gill net suspended in the shallows on the opposite side of the bay off Point Hennequin.

The net had twenty-six living fish. All were marbled notothenids about twelve inches long except one, a Charcot's ice fish—also in the suborder Notothenioidei—twenty-eight inches long, without scales, and streaming with mucus. An armor-plated head was the first third of its body, and through its thin skin I could discern the interlocking plates and sutures of bone. It had a nose like a duck's bill and a mouth with bony lips. As pale as a corpse, only its golden-pupiled eye had any color.

Unlike the invertebrates, the fish fauna of the Antarctic is strikingly poor. Of the

Bill Curtsinger

Amphipods of several species congregate on the underside of ice, below, where they browse for algae and feed on detritus. Like many marine antarctic invertebrates, the starfish, right, striding on their myriad tube feet over an undulating plain of glacial silt, scavenge for seal feces.

Rick Price; Survival Anglia

approximately 20,000 species of fishes on earth, only 120 occur in antarctic waters, and of these, 95 percent are endemic. But the 38-million-year-old fossil beds at Seymour Island, on the other side of the Antarctic Peninsula, have revealed a marine fauna that included catfish, rays, sawfish, and sharks. Most of these fishes slowly became extinct as Antarctica sheared away from the rest of Gondwanaland and gradually cooled. Only the Notothenioidae adapted to the hostile conditions of Antarctica's south polar position.

The challenge for these fishes was to survive subfreezing temperatures without being shattered by ice crystals. The marine invertebrates that live on the bottom of the antarctic continental shelf commonly encounter temperatures as low as 27.1° F, but since their bodies contain the same concentration of salts and minerals (supplemented by sugars, excretory products, and amino acids) as the external environment, they don't freeze. Their strategy is simply to stay away from ice, and since ice floats, this usually means remaining on the ocean floor.

The blood and intercellular fluids of marine fishes are more dilute than the sea, and their tissues freeze at a higher temperature, about 31.7° F. Should an ice crystal even brush against a fish at these temperatures, it can propagate across the skin and penetrate as lethally as a spear. Obviously, ice is everywhere during the winter, and most antarctic fish encounter it without ill effects. How do they survive?

The question wasn't even asked by physiologists until the 1960s, and the answer was one of the surprising discoveries of antarctic science: notothenid fish have organic antifreezes in their intercellular tissues and blood. The antifreezes consist of glycopeptides—molecules made of repeating units of sugar and amino acids—which depress the freezing point of water 200 to 300 times more than would be expected from the physical properties of the dissolved substances alone.

Another problem that notothenids faced as the sea cooled over the millennia was that hemoglobin, the iron-bearing molecule that most vertebrates (and some invertebrates, such as the nemertean worms) carry in their blood corpuscles to transport oxygen, becomes inefficient at low temperatures. Hemoglobin requires a high investment of nutrients and energy to manufacture and push the viscous, corpuscle-laden blood through narrow vessels. As a result, the notothenids gradually became more dependent on direct dissolution of oxygen in their blood plasma, the most extreme cases of this adaptive anemia being the sixteen species of ice fishes.

Ice fishes have been recognized for decades by antarctic whalers, who called them white crocodile fish because of their large, toothed mouths and pale color; even their gills are creamy white, and their blood is transparent. But it was not until 1950 that biologists discovered that the reason for the pallor was that ice fishes entirely lacked hemoglobin and had only vestigial numbers of corpuscles. Ice fishes have anatomical compensations for their anemia: a large heart and wide blood vessels, creating a circulatory system of large volume and low pressure. They are also able to build up high temporary oxygen debts in their tissues, to be repaid later during periods of relative inactivity.

These compensatory adaptations almost seem to be evolutionary afterthoughts that were jerry-rigged to enable the ice fishes to have the energy-saving advantage of thin blood. Now the ice fishes are relegated to the bottom of the bottom of the world, unable to colonize more benign environments and face competition from their red-blooded brethren.

Back in the laboratory, we dissected the invertebrates and fish, searching for parasites. Like pieces of a mosaic, each would bear a clue to the diversity and complex interrelationships of the animals in Admiralty Bay. Now that I had dived in Admiralty Bay, my attitude regarding Antarctica had changed forever: this peninsula no longer seemed to be a sere promontory of rock and snow, supporting a few hardy life forms for a few months of the year.

Terrestrial Antarctica, so attenuated in life and diversity, is surrounded by a sea that is a bouquet of species. These life-cloaked plains and rocks, which begin just beyond the reach of ice and weather, are a frontier outcropping of strange fauna growing perilously close to the lethal instability of the shallow sea. We scientists, pilgrims in the last new land on Earth, are just beginning to understand this unseen underwater realm. □

Tawanasha, left, the wife of the current Kel Fadey chief, traces her descent back to the tribe's female founders. She is in line to become the keeper of the drum, the official instrument used to assemble the tribal sections. Below right: Elbatul, a daughter of the late chief, holds her firstborn.

Where All the Women Are Strong

Wrestling caps a desert tribe's infant-naming ceremony

Text and photographs by Barbara A. Worley

"Tomorrow you shall see a real fight!" Daguna rocked with laughter as she spoke, while the other women in the tent reflected her satisfaction. Six nights before, Daguna's younger sister Elbatul had given birth to her first child, and her female kin, members of the Kel Fadey tribe of pastoral Tuareg, were preparing for two major rituals that celebrate the new mother's coming of age and welcome the newborn: the blessing of the mother's tent and the child's naming ceremony. For the new mother the final honor would be a lively display of wrestling by the wealthiest and most prestigious women. "That is our custom! We will wrestle like you have never seen before!" chortled Kazu, slapping Daguna's shoulder. "If I had some trousers, I could take her down in an instant!"

Daguna, chief Mohammed ag-Sidi's eldest daughter, and her cousin Kazu, the wife of the chief's youngest brother, were waiting out the hottest afternoon hours, when the average temperature in the shade is 112°. They were relaxing in the tent that belonged to Ayshatu, the chief's wife and mother of Daguna and Elbatul. Ayshatu prepared a hefty brew of Chinese gunpowder tea, heavily sweetened and served in shot glasses from a tiny teapot.

Their camp was at a sandy river bed that is dry except for a few days during the rainy season from July to September, when it may flow briefly with the runoff from the Air Mountain range in northwestern Niger. Here, in the desert regions of the south-central Sahara, an environment too arid for farming, the nomadic Tuareg raise camels and goats. They move their livestock from one pasture to the next in an annual cycle, transporting their tents on camels and donkeys.

The Tuareg have never been completely out of contact with the West nor have they been isolated from urban society, yet they take pride in remaining apart and distinct. The desert is clean and wholesome, they say, while the city is filthy and full of evil. Their basic diet consists of milk from their animals (they eat meat only on ritual occasions) and whole grain porridge. Grain, clothing, and other necessities are purchased by the occasional sale of male yearling livestock. Tuareg women conserve surplus milk by converting it to buttermilk and cheese, and during the rainy season they gather wild plants to supplement their diet.

From ancient times to the early twentieth century, the Tuareg dominated the caravan trade across North Africa and the Sahara. They traded and fought with the Pharaonic Egyptians, and they dealt in turn with Phoenician, Greek, and Roman invaders. They adopted camel pastoralism from the Arabs, inventing a lightweight camel saddle that enabled Tuareg men to move swiftly and fight with swords and lances from atop the lithe Tibesti camel. They supplemented their incomes with protection payments from the trans-Saharan trade and by raiding caravans.

The Tuareg became a familiar menace to Europeans who attempted to penetrate and conquer Saharan territories in the late nineteenth century. Because their indigo-dyed garments left a blue cast on their skin, they came to be known as the Blue

Men. To those who admired their gallantry and respect for women they were the "knights-errant of the Sahara." To those who were tricked, ambushed, poisoned, or terrorized by Tuareg warriors they were the "brigands of the desert waste." As the French gained the upper hand in the central Sahara, they were able to subdue the centuries-old power of the Tuareg, using machine-gun fire against the broad swords and addax-hide shields of the Blue Men.

The Muslim Tuareg do not drink alcohol or use drugs, and their men fear the loss of honor that would ensue from beating or raping a woman. Their women are respected and own property in livestock.

At a camp near that of the Kel Fadey, men of another Tuareg tribe, right, race their camels around women participants at the naming ceremony for a new infant. Below: His face veiled according to tribal custom, Elbatul's cousin Najem makes tea.

In many other Muslim societies, women follow the Koranic directive to "cover" themselves, through veiling and keeping to private quarters. In Tuareg society, however, the men wear the veils—not a Muslim custom but one peculiar to the Tuareg and other Berber peoples of the central Sahara. Tuareg women wouldn't consider veiling their faces, and they continue to assert their right to a public presence and to voice their opinions openly.

The Kel Fadey tribe say that their people descend from two sisters who came from the east, bringing with them livestock, herdsmen, and a large wooden drum (the drum, kept by the chief's wife, is used to call the tribal sections together for political or military action). The Kel Fadey reckon their most important kinship connections through women (matrilineally), and so a child's closest relationships are usually with his or her mother's people, especially the mother's brother. In the past, both property inheritance and succession to the chieftainship followed maternal lines, from a man to his sister's sons and daughters. A Kel Fadey child has the greatest respect for his or her father, but looks to the mother's brother for a jovial, supportive relationship, and to the mother's brother's children as best friends and, later in life, the people most likely to be of economic and emotional assistance. The special affection between a sister's and brother's children, called cross-cousins, often entails a level of joking and teasing not appropriate between siblings.

Tuareg women consider themselves very different from men, viewing their own assertiveness as a desirable feminine trait. One of the most valued roles in Tuareg society, according to both men and women, is motherhood. Tuareg mothers can support pregnancy and nurse children, while performing the physically demanding work of pastoralism, milking the livestock and packing and moving the tents (which they own). Mothers have special knowledge of Tuareg cultural practices, herbal medicine, and history and, as a result, are public persons who are sought out for their counsel.

The Tuareg believe that a successful birth requires the mother's focused thought and physical stamina. A woman prefers to give birth in an upright position, and her female kin support her shoulders and back so that she may squat comfortably. An older, experienced woman "catches" the baby as it emerges.

Elbatul's childbirth had been particularly difficult. The baby was turned side-

ways, and Elbatul's mother and mother's sister had worked for almost seven days massaging and pressing on the sides of her abdomen to maneuver the baby into a head-down position for its birth. The delivery was carried out entirely by women in the privacy of Elbatul's own tent, on a bed of clean, fine sand collected and spread inside for the birth.

Several hours after Elbatul's baby was born—it was a boy—her brother sacrificed a goat at a distance from the tent. He took care to bury the blood that had spilled on the earth to avoid attracting the bloodthirsty jinn, or spirits, that live beneath the desert. Elbatul's female cousins simmered the goat's liver in butter and prepared a rich gravy from the meat to help Elbatul regain her strength. She was first offered a tasty concoction of freshly ground millet, crushed sun-dried dates, and cheese topped with sweet buttermilk to encourage her to sit up and eat.

Elbatul's mother washed her grandchild and wrapped him in a blanket of new printed cotton cloth. The infant's delicate eyes and eyebrows were gently outlined with black powdered *tazolt* (antimony trisulfide), a pigment believed to protect against the jinn. The morning after the baby's birth, Elbatul requested a steel knife, which she plunged upright into the sand next to her baby to ward off the jinn. From time to time Elbatul's cousin tossed a pinch of aromatic twigs and spices onto the embers in a small wire brazier nearby, sending incense throughout the tent for the mother's enjoyment, as well as for the protection of the new child.

The Tuareg believe that when a woman goes into labor, she and the unborn child enter a dangerous threshold state. The earth opens up beneath them, forming a grave pit, and remains wide open until the birth of the child. The Old Woman, the elder among the bush spirits, rears her ugly head from the earth and takes a seat in the tent on the side where visitors gen-

A woman, left, pounds millet, a staple food that the pastoral Kel Fadey purchase from farmers living south of the desert. Four-year-old Rakhmatu, below, proudly carries her three-month-old cousin.

erally recline, staring at the mother and threatening serious illness or death. During childbirth and for the six days that follow, the mother and baby are in a state of limbo, because no one can be sure that they will survive.

The Old Woman has a name—Waddawa—but to pronounce it would risk calling her forth and empowering her, so the Tuareg speak of her indirectly. In the six days following the successful birth of the child, the earth gradually begins to close, but the Old Woman is reluctant to leave. On the sixth day, she is finally chased out of the tent and the invisible sepulcher is formally closed: the occasion is the *kishakish* ritual, when the child is brought out of the tent for the first time and is socially born.

According to custom, Elbatul's female relatives performed the *kishakish* ritual at sundown on the sixth day after the baby's birth. They built a fire near the northwest corner of the tent and tossed incense into it. They closed the tent walls so that the only opening remained on its western side, the side away from Mecca, where the Old Woman would be expelled.

Gathering her new grandchild into her arms, Ayshatu joined several other older relatives in a procession counterclockwise around the tent of her daughter, who remained inside alone. Their pace was slow and their steps exaggerated, with feet lifted high into the air, then planted firmly into the sand. The women's clothing, heavily dyed with aromatic blue indigo pigment admired for its soothing and protective properties, lightly brushed the tent as the women encircled it. Young women and children stood back and watched.

The first woman in line carried a knife, which she sharpened rhythmically on each side of a honing rod. The sound of the clashing metal (KISH-a-kish) gives the ritual its name. A second woman carried a handful of freshly collected *afazo* reeds, used daily to sweep the floor of the tent but on this occasion used ritually to sweep out the Old Woman. Third in line was Ayshatu, carrying the baby wrapped in a cloth and clutched to her chest. The remaining women followed close behind.

Invoking the Islamic figures Fatima and Aisha, the daughter and favorite wife, respectively, of the Prophet Mohammed, the women gestured broadly, bringing their outstretched palms down on the roof of the tent with each step to bless it and exorcise the Old Woman, chanting:

KISH-a-kish, KISH-a-kish,
The Old Woman is leaving.
Fatima and Aisha
Are entering!

KISH-a-kish, KISH-a-kish,
Go on out! Go on out!
Fatima and Aisha
Are coming!

KISH-a-kish, KISH-a-kish,
Go on out! Enter!
Fatima and Aisha
Are entering!

KISH-a-kish, KISH-a-kish,
Shoo! Shoo!
Fatima and Aisha
Will be cutting your hair tomorrow!

The women circled the tent three times with slow, deliberate movements. As they

Daguna and Kazu, below, challenge each other to wrestling, part of the festivities surrounding the naming ceremony for Daguna's nephew. Right: Daguna (back to the camera) gains the upper hand.

rounded the tent the third time to the open doorway, they acknowledged the departure of the Old Woman with high-pitched trills and ululations, and the leader came to a stop and tossed her knife into the sand. Little girls scrambled to get hold of the knife, for the Kel Fadey believe that a girl who captures it is guaranteed sex appeal and many suitors.

The following morning the baby received its formal name at a ritual organized by the women. In many other Muslim societies, the naming ceremony, as with all public rituals, tends to be male centered. In a naming ceremony I attended among Hausa-speaking merchants at the nearby oasis of In Gall, for example, men were entertained by a local comedian in the most comfortable quarters and served sumptuous foods, while female invitees watched over their children in separate quarters and ate leftovers. At a Kel Fadey naming ceremony, by contrast, men and women eat, talk, and make merry together.

As the sun rose above the horizon, Ayshatu made tea for her daughter Elbatul. Inside her tent the new mother washed and made herself lovely and fragrant. She put protective black *tazolt* on her own eyes and eyebrows and red ocher powder on her cheeks, nose, and forehead. Her freshly washed hair was left in loose braids to be coiffed later in the morning as part of the celebration.

The closest relatives began to arrive in midmorning, and three of Elbatul's brothers each proposed an Islamic name for the child. They assigned the names to three reeds of varying lengths, and Ayshatu's sister selected one reed, conferring upon the baby his formal Muslim name, Zuher. Later, as he grew and developed a unique personality, the child would likely acquire a personal Tuareg name from his mother, the name by which everyone would come to know him.

Preparations for the noontime feast began. Away from camp, but within earshot of the tent, a man of the blacksmith group within the tribe sacrificed a ram donated by Elbatul's father's brother. As he cut through the animal's jugular vein, he announced the baby's name. The tenderloin meat was secured high up in the rafters of Elbatul's tent, between the acacia root stringers and palm mat roof, for a special meal reserved for her to eat later. The smith kept the head, neck, and hide of the sacrificed animal as his payment, and Ayshatu distributed the remainder of the meat to close female relatives to cook for the feast. On this occasion men take a special interest in the preparation of food. Kel Fadey men often bake bread for family meals, but at this event they also sit near the fire to help tend the meat sauce, normally the task of the women.

Heavy bowls of cooked millet with sauce and trays piled high with meat were distributed to guests in the vicinity of Ayshatu's tent. After the guests began to feast, the cooking pot, in which the ram's intestines were still simmering, became the center of attention. Men related to the new mother through matrilineal kin ties tried to wrestle the pot away from the women, including Elbatul's mother and sisters. The ram's guts, particularly the

membrane lining the stomach, symbolically represent the matrilineal descendants of the two ancestral sisters.

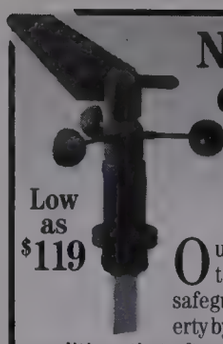
A general free-for-all broke out, as a dozen or so women pressed around the meat pot and held on to it, while their husbands, brothers, and male cousins tried to wrench it from them. At the center of the brawl, Ayshatu held on to the pot for all she was worth. When the men finally wrenched the pot free, they ran off with it, whooping and laughing. The triumph of the baby's mother's brothers in seizing the ram's guts reaffirmed the family's identity and solidarity as matrilineal kin.

After the feast, the men returned to their wives' tents and settled down for an afternoon siesta. But the event was not nearly over yet. Women guests, neighbors, and additional relatives dressed in holiday apparel continued to arrive from all the camps along the valley for tea, gossip, and wrestling, carrying on the celebration until sundown.

For good luck, the baby's hair was trimmed in front and along the temples and fine bits of hair were slipped into cracks in the wood cross-members of the mother's bed. The rest of the clippings were sprinkled into a winnowing basket with freshly ground sweet millet. Elbatul's female relatives tossed coins into the basket and daubed little spots of the mixture on their cheeks, noses, and foreheads. The rest was given to little girls to taste.

Because this was the naming ceremony of a firstborn, one whose mother was directly descended from one of the tribe's founding sisters, the gathering of women was full of enthusiasm. Throughout the afternoon, small groups of women accompanied by their children came from all over. As the visitors arrived, women who were seated ululated or—especially for cross-cousins—rose to greet them. They would shake hands and go through formal greetings, while at the same time renewing the cross-cousin tie by casting humorous, devastating insults on the newly arrived guest. Some of the women became increasingly aggressive in their joking and teasing, verbally assaulting one another in crude terms, laughing the whole time. Pairs of women began to grab each other's shoulders or wrists, with a view to tackling and pinning an opponent.

With mischief in her eyes, Kazu, a robust mother of five, ambled over to where her cross-cousin Daguna was seated. Daguna, also sturdily built, stood up to ex-



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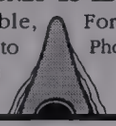

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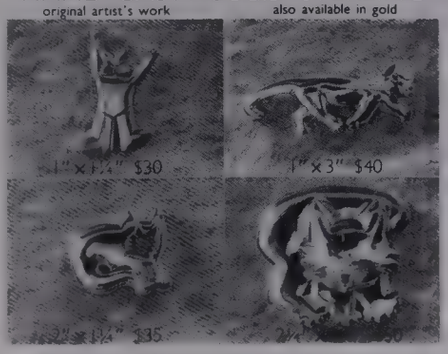

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Kadiya, below, sets up her tent while her youngest child plays on the bed. Eight months pregnant, Kadiya prepares to place the tent supports into postholes she has dug.

change greetings, holding the youngest of her seven children in one arm. Kazu grasped Daguna's wrist tightly. "Well now," she said, "I see you're an old bag and can't fight me any more!" Daguna, acknowledged as her family's champion wrestler, struggled to keep her balance and hold the baby at the same time. After Daguna's seven-year-old daughter came to rescue the infant, everyone moved out of the way as the two women began their skirmish, alternately laughing and clenching their teeth with determination.

Finally, Daguna got a solid grip around Kazu's shoulders and dramatically toppled her. On the ground they continued to struggle, tumbling over and over again in the sand for nearly ten minutes, until Daguna firmly pinned her opponent. While Kazu kicked and squirmed, Daguna stuck her fist in the air repeatedly, like a prize fighter, and looked around defiantly, ululating in triumph. Later, I saw her rubbing her wrist and asked if she'd gotten hurt. She looked me in the eye and grinned, saying, "I never get hurt!"

Tuareg women are strong, accustomed to the exhausting physical work of digging postholes, erecting and dismantling tents, and packing heavy tents and household furniture onto camels and donkeys. Their hands are large from milking the livestock and are roughly calloused from gripping and thrusting the four-foot, heavy wooden pestle with which they pound their family's millet. They do not view their strength as masculine, and they believe their participation in wrestling contributes to the honor they receive as females and mothers.

During the afternoon, a delegation of women from a rival political family approached, causing a major free-for-all. A dozen pairs of women wrestled at once, refereed by several of their relatives. As soon as a woman succeeded in downing an opponent, she would jump up and begin looking around for someone else to confront. Winners would sometimes run up behind a seated woman and pull her along backward if she refused to get up and participate. Only a few of the women really did not want to wrestle, and the others hounded them, pulling at their shoulders and arms. Sometimes the women would trip over one another in their enthusiasm and fall into a heap together.

Women of all ages participated in the rough play. A sixty-year-old woman was caught by surprise as she was attempting

o climb down a ten-foot embankment long the riverbed and was thrown by her ross-cousin over the edge. She lay at the ottom of the riverbed for several minutes efore getting up and dusting herself off, a it stunned, but nevertheless unwilling to cknowledge that she'd been bettered.

The wrestling occupied most of the af-ernoon hours. Some contestants even bit heir opponents and pulled at their large arrings. In all the tussles, however, the vomen joked and laughed. Later, they vould brag about who had trounced vhom, and kid one another about their ruised arms and twisted wrists. Close riendships were cemented, not destroyed, y the competition.

The culminating attraction of the nam-ng ceremony came when a robust sixty-ve-year-old woman approached Elbatul's fty-eight-year-old mother, Ayshatu. A road-shouldered, sturdy mother of welve grown children, Ayshatu was eated in a circle of older women having ea when the contender lowered herself own in front of her and seized her upper rms. The two of them tugged forward and ackward, their pendulous breasts lolling ack and forth, until finally Ayshatu owled over on top of the other woman, ractically flattening her. Laughing and ul-lating, all the women had gathered in a ircle around them.

Later, everybody said what a good arty it had been, and how well the women ad fought, especially Daguna. Ayshatu ad shown her great strength, even at her ge. The ceremony would not have been f any value, they said, if the women had ot wrestled. A woman of high stature, vhich Elbatul certainly was, deserved a reat naming ceremony for her firstborn, ne which had good food, plenty of tea nd chewing tobacco, and good fighting. his naming ceremony had drawn the reatest women wrestlers, and they had erformed well. No one would forget how Daguna had toppled her cross-cousin Kazu. And Kazu would continue to tell veryone that if only she had some men's ants she could certainly beat Daguna. □

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Family Man

Three is the loneliest number

by Roger L. Welsch

A lot of fuss has been made during the past year about the importance of family values, and little agreement has been reached on what exactly those values should be. As usual, I'm a word or two behind things because I am still trying to sort out what a family is. Political moralists long for the good old days of June, Ward, Wally, and the Beaver. But that vision is in reality far too puny.

The lesson came home to me in vivid fashion twenty-six years ago when my first wife gave birth to our son. A couple of days after we welcomed Chris into the world, I drove to the hospital and went to the front desk. The nurse went to get my wife and son and brought them to me at the hospital door. "There you are, Mr. Welsch," she said, handing me five diapers, a bottle, a sample box of formula, a blanket, my wife, and a baby. "Goodbye and good luck."

A few weeks earlier I had bought a used car from Weird Wally. Wally is weird but he can be down-to-earth when he has to be: "I need to see your insurance papers, driver's license, and loan agreement." To get those three documents required a written exam, a driving test, proof of identification, a photograph, and a demonstration of financial responsibility. It took me days to get the stuff together. When they hand over a car to you, they want lots of evidence that you have some idea what you are doing. A baby? "There you are, Mr. Welsch. Goodbye and good luck."

That was only the beginning—for both the baby and the automobile. Two or three times a day my wife called my mother, her aunts, friends, and neighbors to find out how to run this little mechanism we called Chris. "What's it mean when he spits up clear stuff and cries with little short blasts like 'Wahn wahn wahn'?" Two or three times a week I called my father, my pals, and the guy at the filling station to find out how to run this mechanism I called "that damned Ford." "What's it mean when it makes clunking sounds in the rear wheels like 'Wunk wunk wunk'?"

Forget single mothers. Here we were, the ideal American family, and still we were woefully understaffed. Generally, throughout a good part of the world a family includes at least a husband, a wife, their children, and the surviving grandparents. That's the way it was in the United States, too, until fairly recently. If that tradition hadn't faded, my mother and father and my wife's father would have been living with us—available to serve as built-in baby sitters, cooks, mechanics, therapists, and, as we later needed, chaperons and marriage counselors. The concept of family held by those who consider themselves defenders of "family values" turns out to be a radical departure from tradition.

Even the old-fashioned family arrangement—parents, children, and surviving grandparents—is a trimmed down version of the *Ur*-family. Within my foster culture, the Omaha tribe of eastern Nebraska, a family is much wider. I once asked a niece of my Omaha brother, Buddy Gilpin, "Where is Buddy?"

"Dad is in Lincoln," she said.

Okay, so her dad is in Lincoln, I thought. What about Buddy? I tried again. "But where is Buddy?"

She looked at me curiously and tried again, "Dad is in Lincoln."

Then it dawned on me. Within traditional Omaha culture, when a man died, his brother married the widow—a crucial economic and cultural safety net in a society where a woman alone was in peril. Similarly, when a woman died, her sister married the widower—to keep house, support the hunting, provide food, make hunting tools and clothing, and care for his children, who otherwise would have no one. Thus, your mother's sisters were potential mothers for you, while your father's brothers were potential fathers—and that is how they are labeled in the Omaha kinship system. My brother Buddy, this woman's "uncle" in standard American terms, was in her world and mind, her father, just as surely as her biological father.

Within Omaha culture, kinship terms are also used honorifically whenever a kinlike relationship is established. For example, Omaha children, even adults, frequently move from one biological family unit to another for any number of reasons. A family with economic problems might ask another family to take children for a year or so until things get better, or a child who shows a talent for singing may be sent to live for a while with a family noted for its repertoire of Helushka songs. As a result, members of the host family are viewed as kin. I once sent a child of mine to live with Comanche friends because they kept horses, my daughter loved horses, she was having a lot of problems, and we all thought a summer with the Comanches and their horses would help. So off she went—not as a gesture of despair but of love. My daughter now has a Comanche uncle and aunt and cousins.

Among the Omahas several people were especially kind in guiding me through my efforts to understand the ways of the tribe. They weren't just friendly—they took chances for me, they stood beside me in important ceremonial trials, they loved me, and I certainly loved them. So I wound up with an Aunt Elizabeth, Uncle Clyde, Cousin Dennis, Cousin Ago, among others. And they are as close to me as those biological brothers and sisters of my German father and mother I call "aunt" and "uncle."

And that isn't all there is to an Omaha family. I was adopted by Buddy Gilpin as his brother in 1967, during a long evening of solemn, yet joyful ritual on the Omaha reservation near Macy, Nebraska. In receiving my Omaha name I not only ac-

uired a brother but entered the roster of
ıe Wind Clan.

The following week I was at another
maha celebration, and when the singers
egan the song called "The Half-Breed
ance," I rose to dance. My Omaha
iends had always made a fuss about
aking me get up and dance "The Half-
reed Dance" because they said I ate so
uch corn soup and frybread and spent so
uch time among them, that by ingestion
nd association, I had become a half-
reed. This time, however, my friends
ushed to pull me back to my seat. I could
o longer dance "The Half-Breed Dance,"
ey explained, because I was no longer a
alf-breed. Or a white man. The adoption
eremony was not merely a gesture. In the
inds of my friends, I had become an
maha, a part of The Family, and there-
ore I had a whole bunch of relatives I
idn't even know about.

In fact, nearly everyone I know in the
maha tribe calls me "uncle" or "cousin"
r "nephew." Old men of high station call
ıe "uncle." Children call me "nephew."
eople I've never seen before call me
Dad." I might just as well go ahead and
ay that the entire Omaha tribe of 5,000
ouls is my family.

Of course, here at the farm there is my
amily of my wife and child, but we three
re a pretty lonely tribe, out here in the
orld all by ourselves. So, even though I
ve 150 miles from the Omaha reserva-
on, I find a lot of comfort in knowing that
ll of those relatives of mine are out there
henever I need them.

And surely, surely, one of them has to
e a good auto mechanic.

olklorist Roger L. Welsch lives on a tree
arm in Dannebrog, Nebraska. His latest
ook, Touching the Fire: Buffalo Dancers,
ıe Sky Bundle, and Other Tales *(Villard*
ooks, 1992), explores rites, objects, and
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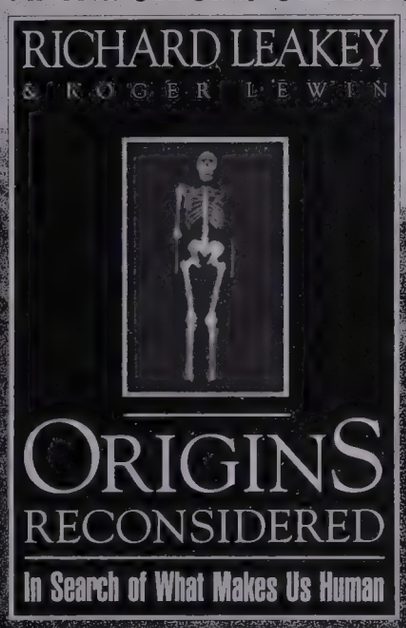

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Alexander Springs, Florida

by Robert H. Mohlenbrock

Issuing clear water at the rate of seventy-eight million gallons a day from a large limestone cavern twenty-five feet belowground, Alexander Springs has the greatest flow of any natural spring on U.S. Government land. The 300-foot-diameter pool it supplies is the main attraction of a recreation area in Ocala National Forest, in the center of the Florida peninsula. At a constant 74° F, the pool is a favorite of swimmers and scuba divers. The crowds do little harm to the environment, although they stir up sand on the adjacent beach, sending it into the rolling water.

The cavernous limestone that conducts water to Alexander Springs was laid down by a process that began several tens of millions of years ago, when a warm, shallow sea covered what is now peninsular Florida. Small invertebrate animals and plants died and their hard parts accumulated on the sea floor, forming a layer of limestone bedrock several thousand feet deep, over which additional layers of sandy limestone and sand were deposited. After a fall in sea level, the present peninsula emerged as dry land, and the deposits became subject to erosion. Today the Ocala area is a rolling landscape that consists mainly of exposed sand, with a few limestone outcrops.

The pool created by Alexander Springs lies in a shallow basin. Among the trees that grow nearby in the sandy soil are cabbage palms, water oaks, and willow oaks draped with Spanish moss. Probably no oak species in the country has as many leaf shapes as the water oak, varying from highly lobed to not lobed at all. And willow oak, except for its acorns, looks little like an oak, because its leaves are extremely narrow, toothless, and lobeless.

In the deeper parts of the spring pool, threadlike stems of naiad, a flowering plant with microscopic flowers, form mats just beneath the surface. The water along the shoreline is clogged with water hyacinth, whose gorgeous pink flowers can scarcely compensate for its aggressive nature. A native of South America, it was introduced as a novelty at the 1892 Louisiana Exposition, from which it spread with

Cabbage palms line the pool fed by Alexander Springs.
Helen Longest-Slaughter; Nature Images

Alexander Springs

Supervisor
National Forests in Florida
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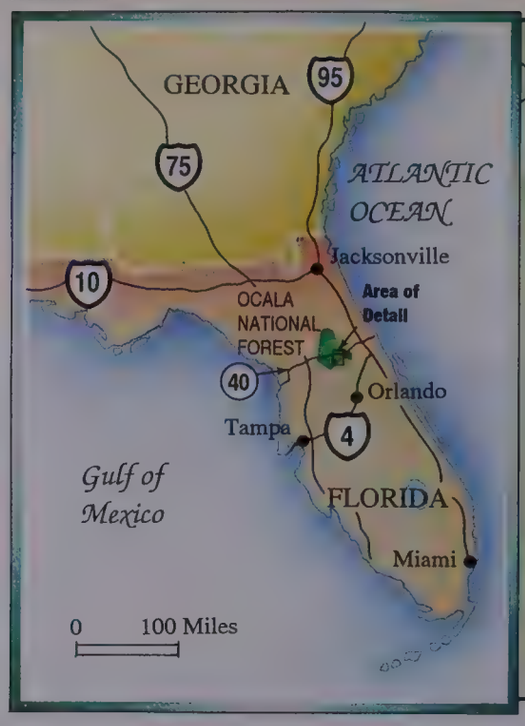
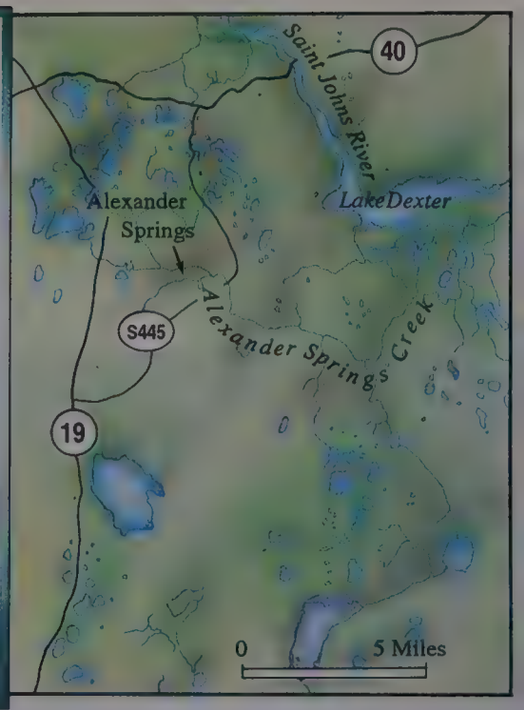
Joe LeMonnier





Shermanlike speed across the south. But the water hyacinth also has its share of virtues. It is able to absorb toxic chemicals from polluted water, and its massive rhizomes provide a perfect home for the inch-long apple snail with its paper-thin, brown shell. At Alexander Springs, the apple snail is the only source of food for the limpkin, a brown, awkward-looking, two-foot-tall bird that tiptoes on spindly legs along the water's edge.

The marshy soil adjacent to the water hyacinth is home to several small wetland species of flowering plants, including pennywort, whose rounded leaves disguise its memberhip in the carrot family; the nodding frog-fruit of the verbena family; and the weak-stemmed bedstraw, with whorls of narrow leaves up and down its stem. Growing as a web over much of the vegetation is the slender, viny Florida vetch, whose pale lavender, sweetpea-shaped flowers appear in May and June.

From the pool, water channels into Alexander Springs Creek, which flows through a cabbage palm–hardwood "hammock," grassy wetland flats, and a shady hardwood forest, to empty into the Saint John's River sixteen miles to the east. A hammock, or hummock, is a slightly elevated tract of forest in a marshy area. The one through which the creek flows is covered with an unusual mix of temperate and subtropical vegetation. Sixty-foot-tall cabbage palms from the tropics stand beside red maples, commonly associated with New England, and sweet bay magnolias and Carolina ashes from the Appalachians. In the shrub layers, saw palmettos of the tropics live with wahoo of the eastern United States and leatherleaf leucothoe of the Appalachians. Virginia creeper and poison ivy, so common in the Northeast and Midwest, climb on the same trees as do the Florida wild yam and the climbing hydrangea of the Southwest.

Ferns, many with three-foot-long leaves, create impenetrable thickets in places. Common temperate species are royal fern, cinnamon fern, netted chain fern, and marsh fern, while golden polypody is subtropical. The small gray polypody, which has a broad range, often grows as an epiphyte (air plant), blanketing the upper side of tree branches. Shallow depressions in the cabbage palm-hardwood hammock periodically retain water, supporting such wetland plants as arrowhead, lizard's-tail, and an assortment of grasses, sedges, and rushes. Most are temperate but at least one, Florida brookweed, is a subtropical species. To protect both the ecosystem and the visitor, the Forest Service has constructed a trail, much of it on elevated boardwalks, throughout this jungle.

One unusual plant in the hammock, whose divided leaves suggest a cross between a fern and a palmetto, produces cones resembling those of a pine. Known locally as coontie, it is a cycad—a species that is not a fern or conifer or flowering plant, but is a member of a primitive group transitional between ferns and palms. Today only a few cycad species exist in the world, although the fossil record shows that they were the dominant plants 200 million years ago. The coontie is considered rare in most parts of Florida, but Indians and early European settlers used its starchy underground stems as an important source of food.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.

A limpkin feeds on an apple snail.
John Hendrickson

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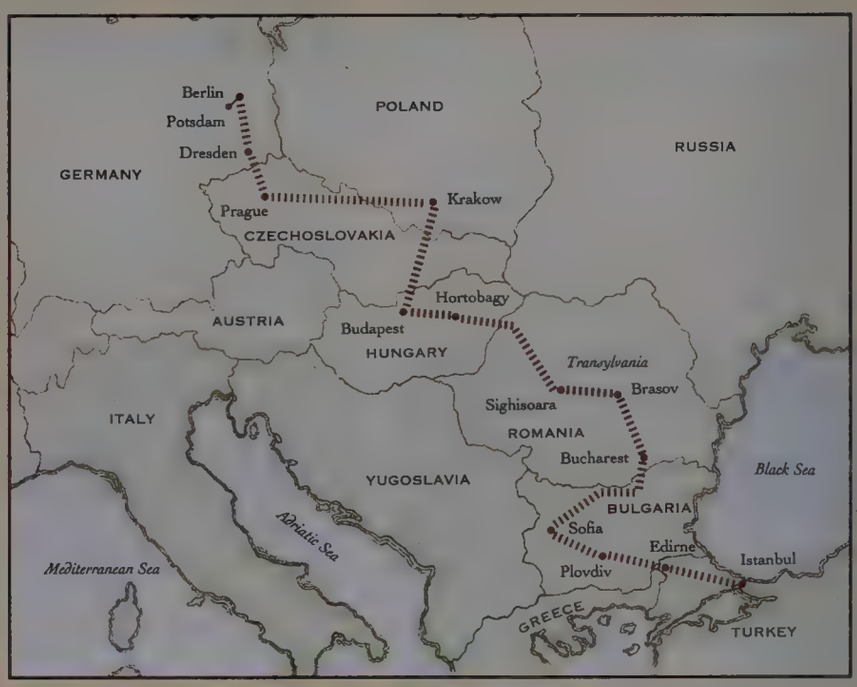

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Too Much Light on the Subject

by Gail S. Cleere

For many people, the dark of night is something to be feared and, if possible, conquered with bright lights. Astronomers, however, have come to regard such lighting as a form of pollution. At its worst around major urban areas, unwanted light obscures all but the brightest stars and planets. Illumination from street lamps, advertising signs, and other sources is scattered and reflected by water vapor and dust in the atmosphere, causing the night skies to glow a dull pink. Few places in the country have skies dark enough for what professional astronomers call "deep-sky observing," in which the targets are faint, distant objects such as clusters, nebulae, and galaxies. In his book of essays, *Saving Graces,* Roger Swain wrote, "For most of us the nights are not what they used to be. Sunset near human habitation is not followed by the Stygian darkness of antiquity but by an artificial dusk that is turned off only by dawn."

Light pollution, a result of urban growth, is destroying our view of the universe. In many places there's so little real darkness that we have forgotten what it's like. Whole new generations will never see the Milky Way simply because they can't. Astronomers were the first to recognize that legions of humanity wouldn't know a constellation from a prune danish, let alone the brilliant arm of our galaxy.

In 1988 a commission of the International Astronomical Union met in Washington, D.C., to discuss the problem of light pollution. At the meeting this summer of UNESCO's Division of Basic Sciences in Paris, the problem was discussed further. David Crawford, an astronomer at Kitt Peak National Observatory, and president of the IAU's Commission on the Protection of Observatory Sites, said, "We have created a permanent twilight in many places. We must learn about better lighting. Neither the birds nor the astronauts need all the light we are throwing up into space." Dan Brocious of the Smithsonian's Whipple Observatory in Arizona added that "at least $1.3 billion a year is spent in the United States on electricity that is wasted to light up the night sky. This is more than the entire budget for astronomy in the United States."

But there's a move to change this. Campaigns have been mounted to curb excessive and unnecessary lighting near observatories. Cities in Arizona and elsewhere have passed ordinances requiring that lighting be shielded so that illumination is directed downward rather than up to the sky. Tucson, Arizona, near which several major observatories are located, requires that all outdoor advertising signs lit from below with lights directed upward must be turned off by 11:00 P.M. The use of low-pressure sodium bulbs for street lighting has also been encouraged because such bulbs emit a relatively narrow spectrum of light and thus interfere less with astronomical observations.

Nobody advocates bad lighting or light pollution—not even the lighting industry—and that is precisely why many in the industry support the work of Dr. Crawford's International Dark Sky Association, an organization formed to combat light pollution around the world. For more information, write: Dr. David Crawford, International Dark Sky Association, 3545 North Stewart Ave., Tucson, AZ 85716.

The Solar System in November

Mercury swings from the evening sky to the morning sky this month, passing between the earth and sun on the 21st. At the beginning of November, this swift, elusive planet is low in the southwest, setting about an hour after the sun. By month's end, Mercury rises an hour and a half before sunrise in the southeast.

Venus is low in the southwest just after sundown, growing brighter and more prominent all month. On the 27th, Venus is just south of the three-day-old waxing crescent moon, Uranus, and Neptune. Throughout history, Venus has startled us with her brilliance, frequently causing, as astronomer Bob Berman put it, "Earth's inhabitants to go on a binge of misidentification." A French port commandant in 1835 mistook Venus for an enemy balloon shining lights on his harbor installations and he sent gunboats to shoot it down; in 1945, Allied bombers attempted the same feat as they returned from a mission over Japan; and as recently as 1969, Jimmy Carter, a trained navigator and future U.S. president, mistook Venus for a UFO. Achieving magnitudes in excess of -4.0, Venus can even be seen in daytime if one knows exactly where to look.

Mars pays the twin stars Castor and Pollux a fairly close call this month. The planet rises about 9:00 P.M., EST, at mid-month and is high along the meridian (your north–south line across the sky) at 4:30 A.M., EST. Look for Mars high above and to the east (left) of winter's most magnificent constellation, Orion the Hunter. On the 15th, Mars is just north of (above) the waning gibbous moon. All year long Mars has been moving eastward in the sky relative to the background stars. This is the normal way of things; a "bird's-eye" view north of the Solar System would show all planets, including earth, moving counter-clockwise (or eastward from our earth-bound perspective) around the sun. On November 29th, Mars appears to end its eastward motion against the background stars, after which it drifts westward. This retrograde motion of an outer planet (such as Mars) occurs when earth overtakes the planet in its own speedier orbit around the sun, causing the outer planet to appear for a time to move backward. The retrograde motion of Mars will continue until mid-February 1993, when the red planet resumes its eastward motion.

Jupiter remains in Virgo this month, a very bright object (-1.8 magnitude) in predawn eastern skies. This giant planet can be seen just above-right of the bright star Spica (+1.0 magnitude) in the same constellation. On the 20th, both are near the waning crescent moon.

Saturn is low in the southern skies after sunset, and sets around midnight. Look for the ringed planet midway between the bright first-magnitude star Altair, high in the southwest, and the bright first-magnitude star Fomalhaut, low in the southeast.

ELESTIAL EVENTS

turn will be the only bright object in the gion between these two stars.

Uranus and **Neptune** can be seen with noculars this month by scanning the ies on the 27th just after sunset, and oking between the three-day-old cres-nt moon and Venus. If you have dark, ear skies, look for two bluish green star-e objects, with Neptune, the fainter one, ing closest to the moon.

Pluto is in conjunction with the Sun on e 15th, thus lost in the solar glare all onth.

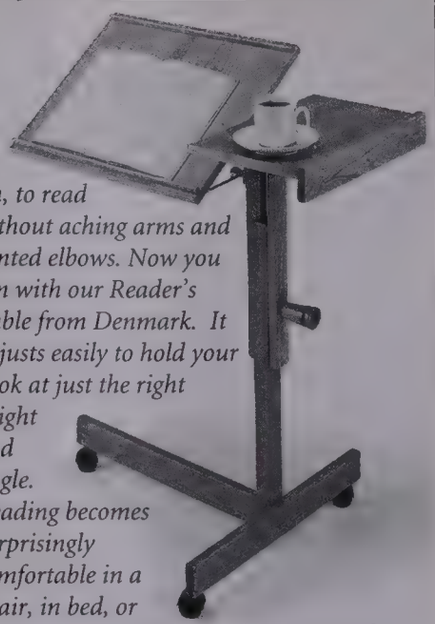
First-quarter **Moon** occurs on the 2nd at 11 A.M., EST; full moon occurs on the th at 4:20 A.M., EST; last quarter on the th at 6:39 A.M., EST, and new moon oc-rs on the 24th at 4:11 A.M., EST.

The Leonid Meteor Shower will peak the evening of November 16-17, but is year the moon will be up after mid-ght and may hamper viewing somewhat. he Leonids are an interesting shower—mpletely unpredictable. The shower has iled to show up at all in some years, and t in 1933 the Leonids were described as ing "like a child's sparkler held against e sky." In 1966, they burst over the cen-al and western United States in the great-t meteoric display in history (150,000 eteors an hour for forty minutes.) Spec-cular displays such as these tend to occur very thirty-three years.

The Leonids are remnants of Comet empel-Tuttle, first seen in France in De-ember 1865 by Ernest Tempel. One onth later the comet was discovered om the rooftop of the Naval Observatory downtown Washington, D.C., by an am-eur astronomer, Horace P. Tuttle. As the ivil War was ending, Tuttle received per-ission from the Navy Department to aul his small telescope up to the Observ-ory's rooftop to search for comets.

ail S. Cleere writes on popular astron-my and is a founding member of the nternational Dark Sky Association, an rganization dedicated to preserving the kies for astronomy.

Lay Down Your Arms



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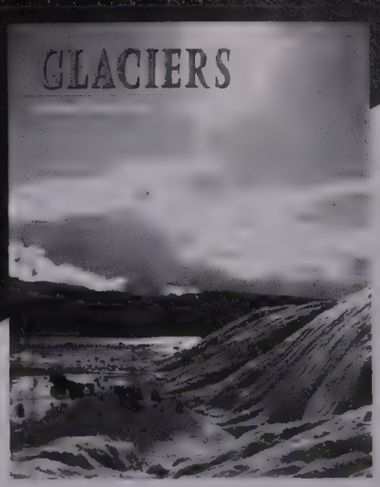

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At the American Museum of Natural History

Galaxies and Dark Matter

Vera Rubin, observational astronomer at the Department of Terrestrial Magnetism, Carnegie Institution of Washington, will explore the geography and structure of the universe in a slide-illustrated lecture, at 7:30 P.M. on Tuesday, November 10. The lecture is part of the Frontiers in Astronomy and Astrophysics series and will take place in the Planetarium's Sky Theater. Tickets are $8 ($6 for members). For information about ticket availability and other Planetarium events, call (212) 769-5900.

Contact: Cultural Change, Alternate Perspectives

In conjunction with the Columbus quincentennial this year, the Museum's Education Department will continue offering weekend programs that present the cultures of people contacted by Europeans. Performances by the Viva Brazil Dance Company, the Louines Louines Haitian Dance Theater, and the Ramnarace family of the America Savashram Sangha group will be among the programs. For a complete schedule, including films that will be shown each weekend, call (212) 769-5315.

Naturemax

Starting Sunday, November 1, and running through Friday, April 30, 1993, Naturemax Theater will be showing *Tropical Rainforest* (daily from 10:30 A.M. through 4:30 P.M., every hour on the half hour). From rain forests of Malaysia, Costa Rica, and Queensland, Australia, choreographer/dancer Geoffrey Holder narrates the story of their 400-million-year evolution and the biological diversity of animal and plant life found within their borders.

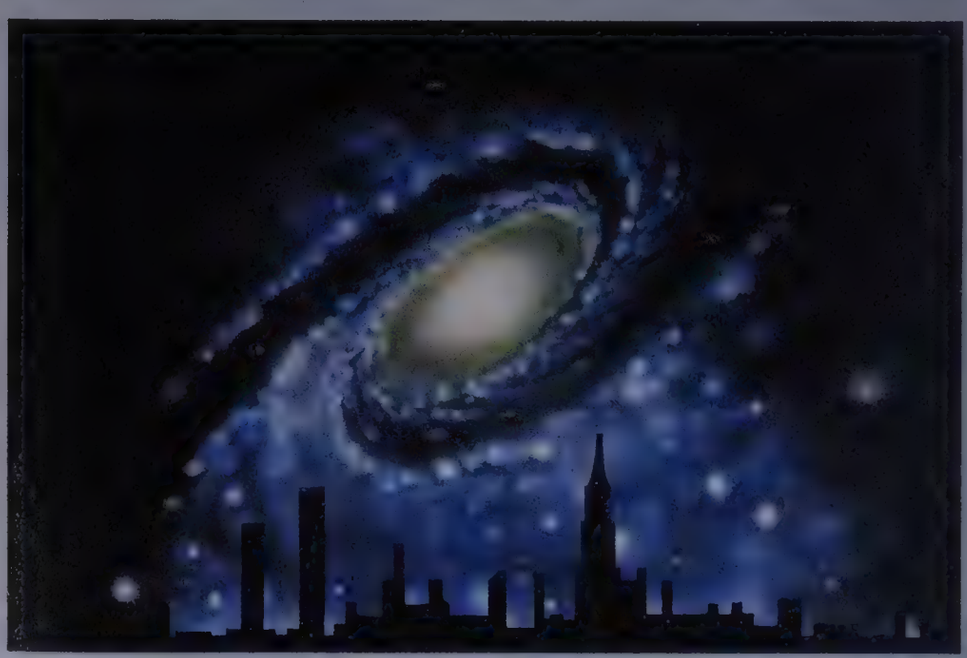
On Friday and Saturday evenings at 6:00 and 7:30 P.M., *The Magic Egg* will be included in the program. This computer-animated journey showcases the technology of IMAX filmmaking.

Tours in Sign Language

Tours of Museum highlights in sign language will include the 50-foot-tall barosaurus, the 94-foot-long blue whale, and the 34-ton meteorite, among other exhibits. Starting at 2:00 P.M. on Saturday, November 14, Wednesday, November 18, and Saturday, November 21, tours will leave from the information desk in the second-floor rotunda and are free of charge with Museum admission. For further information, call (212) 769-5566 (voice).

Sci-Fi Classics

The first of six classic science-fiction films will be presented on Saturday, November 7, in the Kaufmann Theater at 3:00 P.M. Before showing the 1951 film, "The Day the Earth Stood Still," Brian



Galactic City, *a painting by Brian Sullivan* Hayden Planetarium

llivan, the Hayden Planetarium's pro-
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ars. Tickets are $7 ($4 for members).

EMBERS' PROGRAMS
Sidney Horenstein, the Museum's co-
dinator of environmental public pro-
ams, will discuss New York's water
pply system—from Manhattan's first
thorized municipal well in 1658 to
day's reservoir systems, which supply
ater to more than nine million people.
he slide-illustrated talk will be given on
iday, November 6, in the Kaufmann
heater at 7:00 P.M. Tickets are $10 ($5
r members).
Former chief scientist at the National
ceanic and Atmospheric Administra-
on, Sylvia Earle, marine biologist,
eanographer, and aquanaut, will dis-
ss subsea technology and wilderness
nes. Her talk "What Price Oceans?"
ill be held in the Main Auditorium on
hursday, November 12, at 7:00 P.M.
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For details about members' programs,
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hursday, November 5, at 7:00 P.M. in
e Main Auditorium. In a slide-illus-
ated talk, mountaineer and scholar
dwin Bernbaum will tell the story of
s journey to Kenya and Kilimanjaro,
e sacred peaks in East Africa, and his
xploration of the area's diverse wildlife,
egetation, and peoples. The program
ill be held on Tuesday, November 10,
7:00 P.M. in the Kaufmann Theater.
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or more information about the fall lec-
re series, call (212) 769-5310.

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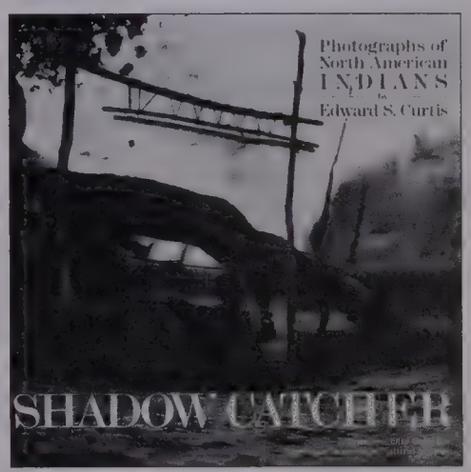

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History in a Stewpot

Irish and Yoruba traditions meet on the island of Montserrat

by Raymond Sokolov

Thomas West is standing uphill from a crowd of his happy neighbors. He has a goat with him, trussed and hung from a branch. He and the others have come up a steep road from their seaside village of Saint Patrick's to Galways, a ruined seventeenth-century sugar plantation. The site has been partly restored under the direction of Lydia Mihelič Pulsipher, a cultural geographer from the University of Tennessee. She has been coming to the Caribbean island of Montserrat for many years to do the research that recently culminated in the section on Montserrat in the Smithsonian's "Seeds of Change" exhibition.

Pulsipher has also set in motion this gathering—a feast centered on Montserrat's famous special dish, goatwater. This traditional goat stew is wrapped in mystery. Recipes are not hard to find, and goatwater has even made its way to New York and onto the menu of a Greenwich Village restaurant, Caribe. The mystery of goatwater is not its nature, but its origin.

In her essay on Montserrat in the "Seeds of Change" catalog, Pulsipher wrote that

In Montserrat, preparing goatwater is a communal affair. Here, the goat has been butchered in preparation for an outdoor feast on the grounds of Galways, a seventeenth-century sugar plantation.
Lydia M. Pulsipher

MATTER OF TASTE

e traditional preparation of goatwater in-
udes elements of Yoruba ritual preserved
y the descendants of slaves from West
frica. Another theory, entertained by the
Iontserratian writer Howard A. Fergus, is
at goatwater is a form of Irish stew.

Since Montserrat was settled by Irish
atholics in the early seventeenth century,
is is not a wild claim. Before there were
lack slaves on the island, Irish indentured
ervants worked the cane fields. The
fricans who replaced them eventually
ssimilated into a way of life that even

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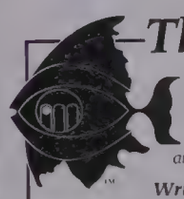

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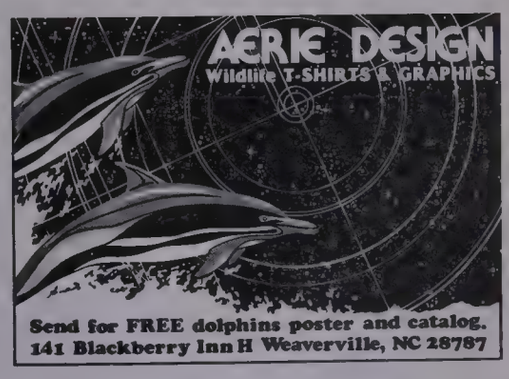

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today has a Hibernian cast to it. Typical names of black Montserratian families are Riley, Farrell, Ryan. Montserrat is known as the Caribbean's emerald isle, and you get a green shamrock stamped on your passport when you arrive. So the national dish might easily be a version of Irish stew embraced by transplanted Africans. But it might just have easily have survived from tribal days in West Africa, as have such other dishes as Brazilian *acarajes* (black-eyed pea flour fritters) and their northern, maize-based cousins, hush puppies.

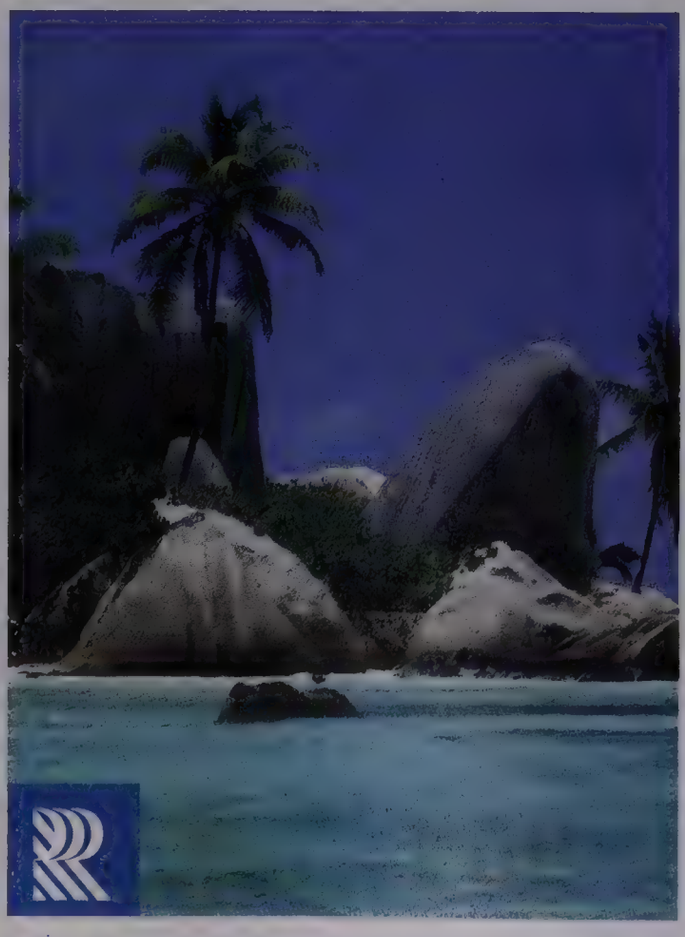
Barring the lucky if improbable discovery of a clarifying seventeenth-century document, the first step in sorting out the question at this late date would be to observe the preparation of goatwater in an unselfconscious setting on Montserrat. So I went there and asked Pulsipher, as much an insider as a North American white could hope to be, to arrange an event. There is no denying, then, that this goatwater feast was staged for my benefit and at the expense of this magazine, but I have reasons to believe that what I saw was no different from what the people of Saint Patrick's would have done if they had been entirely on their own.

The first reason is that the goatwater was prepared as a communal event. I did not request a feast, but I got one. No one even considered just taking me home and cooking a stew on the stove—or starting with a live goat in a private setting. So it seems fair to say that my goatwater was typical in being a public feast. Second, the slaughter of the animal was also public. Clearly, the killing and butchering could have been done in an enclosed area, but Thomas West set up his alfresco charnel house in view of everyone. To my eye, he looked a bit embarrassed, as if he might have preferred to get the job done more discreetly, but he went ahead with it in the way that a slightly reluctant performer soldiers through his act—because there is no other way to do it.

Third, the slaughter and the cooking occurred outdoors, over an open fire with improvised pots (two large biscuit tins). Was this just a surrender to necessity and convenience? A way to feed a lot of people in one place, and without the fuss of dragging a kitchen up the hill to Galways? Or was it part of the tradition?

Not obviously burdened by such thoughts, Thomas West raised his machete (he would call it a cutlass) and dispatched the goat. It was an expert performance, methodical, practiced, almost awesome in its economy of motion and neatness. Having skinned and gutted the animal, he quartered it without ever having to let the main carcass touch the ground. A group of women tending a fire nearby in the shelter of a stone archway finished the job with knives, leaving the bones attached to the meat. This seems to be canonical, as it is specified in the most widely circulated printed recipe, in *Montserrat Cookbook* (published by The Montserrat Old People's Association in 1973 and still in print).

After cutting the meat, the elderly women cooks washed it in salt water, also specified in *Montserrat Cookbook*'s recipe. Up to this point, the classic methods for goatwater and Irish stew are basically the same—the meat is cut in pieces and left unboned. But the rinsing in salt water is unique to goatwater. It does not take a Ph.D. in anthropology to speculate that this may be a vestige of a purification rite (an analogy to the rinsing of kosher meat is hard to avoid). And the possibility that the salt water is a survival from a time when the meat was rinsed in the sea is attractive (especially in the light of seawater immersion rites brought from Africa to



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rtheast Brazil, which are still widely
cticed today).

At this point, Irish stew and goatwater
onverge. Solid ingredients are im-
rsed in plain water, seasonings are
ded, and cooking continues (at Gal-
ys, the semi-detached metal tops of the
cuit tins were folded back over to their
ginal position, to form lids) until the
at is tender. In other words, looked at
irely in terms of basic structure, Irish
w and goatwater are quite similar (salt
ter immersion aside). They seem to dif-
primarily in their ingredients.

An Irish stew conventionally is a lamb
w. Goatwater obviously is a goat stew.
th dishes contain onions. Irish stew has
tatoes while goatwater gets its starch
ckening from a slurry of raw flour
ded toward the end of the cooking.

Finally, there is the matter of color. Irish
w is an unbrowned stew. This is not a
iality. The celebrated Parisian restaura-
r Denis once told me he considered the
ission of an initial browning stage for
lamb in Irish stew as its defining char-
teristic. The French analogue, *navarin*
agneau, starts out like most stews with
cubed meat being seared and its juices
ramelized, in order to produce a dark
lor.

Goatwater, however, is unbrowned, just
e Irish stew. Yet goatwater chefs make
for this by adding flour and a commer-
l browning preparation. To a French
ok, this would amount to the addition, in
o stages, of what classic French cuisine
es in one, with a roux (flour browned in
tter).

As it happens, roux is typical of New
orld Creole cooking, something
bitués of New Orleans cuisine know
ll. And so, it is entirely possible (even
ely, considering the clumsy, ad hoc
thod) that the flour-and-browning stage
goatwater is a New World fillip added
her to an African original or to Irish
w, in an attempt to assimilate a method
ontserratians would have picked up
m non-Montserratian islanders or from
itish masters who wanted color and
ckness in the stews their cooks had first
rned to make from the island's Irish in-
bitants.

Either way, the flour and browning in
atwater are not essential to a definition
the original dish, although contempo-
y goatwater lovers see this stage as cru-
l (one young man from Saint Patrick's
d me that a goatwater rose or fell on the
esse and timing of the addition of the
ur). Could it be that this shortcut to thickening started out as a response by those early Irish cooks to the lack of potatoes on the island? I don't think so, since many other fleshy native tubers were available on Montserrat from the earliest days of settlement and could have served as potato substitutes.

A better question is: Did Irish stew in the early seventeenth century have potatoes in it? C. Anne Wilson, in her authoritative *Food and Drink in Britain, From the Stone Age to the 19th Century* (1973), finds evidence that soldiers who returned to England before 1657 "gave reports of whole fields in Ireland overrun by potatoes." This suggests that the Irish love affair with the potato was in full force among poor Irish peasantry at about the same time Irish indentured workers were being settled on Montserrat. But the tropical conditions on Montserrat would not have favored the cultivation of the potato as a cheap staple crop. So if goatwater did begin in early colonial days as an offshoot of Irish stew, that imported ragout would not have had potatoes in it. In other words, the seventeenth-century stew the Irish would have improvised on Montserrat must have been a mixture of meat and onions and seasonings. And no potatoes.

Thus the only difference between this hypothetical potatoless early-modern Irish

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stew and contemporary goatwater (if we overlook salt-water immersion and, possibly, flour and browning) is in the meat. But that is only an apparent dissimilarity if we accept the tradition, reported by Malachi McCormick in *Irish Country Cooking* (1984), that the original Irish stew was originally made with goat (the meat of a male kid).

Goatwater could easily have begun, then, as an unbrowned stew of goat and onions originating in Ireland and brought to Montserrat by the island's Old World settlers. Over the centuries, black Africans imported to the island as slaves adopted the European stew and added local spicing and a primitive form of the roux popular throughout the region, especially among French settlers on nearby Guadeloupe.

This scenario has an appealing coherence, but there is no reason why the sam stew (with some American starch and co oring element as the precursors of flou and commercial browning) couldn't hav originated in West Africa and crossed th Atlantic westward in the minds of thos slaves who were offloaded at Montserra This African scenario has the advantage o easily explaining goatwater's salt-wate immersion and the public sacrifice of th eponymous goat.

Both stories make sense, the Irish an the African. Barring the emergence o hard evidence one way or the other, I ac cept them both, two strands of culinar history meeting on one green island.

Raymond Sokolov is a writer whose spe cial interests are the history and prepara tion of food.

Irish Stew

(Slightly adapted from Malachi McCormick's *Irish Country Cooking*, Clarkson Potter, 1984)

- *2 pounds lamb (best end of neck)*
- *8 medium-size potatoes, sliced but not peeled*
- *3 large Spanish onions, sliced*
- *2 tablespoons chopped fresh parsley*
- *1 tablespoon chopped fresh thyme or 1 teaspoon dried thyme*
- *Salt and pepper*

1. Trim excess fat off meat. Do not remove the bone. Cut the meat into 2-inch chunks with a cleaver or knife.
2. Put a layer of sliced potatoes in a large stewpot, followed by a layer of onions, and then a layer of meat chunks, sprinkling parsley, thyme, and salt and pepper between the layers. Continue layering and sprinkling, ending with a layer of potatoes.
3. Add 2 cups water, cover, and bring to a boil. Reduce heat and simmer gently for 2 hours or until the meat is very tender. You may have to stir and add a little water from time to time to keep the liquid level up. Be careful not to overdo it, however: Irish stew is a thick stew and should not drown in its own broth.

Yield: 4 to 6 servings

Mary Lake's Goatwater

(Slightly adapted from *Montserrat Cookbook* (The Montserrat Old People's Association, 1973)

- *2 quarters goat or sheep*
- *Salt*
- *4 onions cut up*
- *Herbs and chible (local name for scallions and thyme)*
- *¾ cup cooking oil*
- *Handful fresh marjoram*
- *4 cloves garlic, minced*
- *1 tablespoon whole cloves, crushed*
- *1 tablespoon mace*
- *2 tablespoons catsup*
- *1 hot green pepper, whole*
- *Pepper*
- *2 cups flour*
- *Browning (Kitchen Bouquet or Cross & Blackwell)*
- *Whiskey or rum (optional)*

1. Cut the meat into 2-inch cubes, being sure to leave bones in.
2. Wash in salt water and place in a large saucepan. Cover with cold water, bring to a boil, and simmer, covered, for 5 minutes. Skim and continue simmering, covered, adding onions, herbs and chible, oil, marjoram, garlic, cloves, mace, catsup, green pepper, salt and pepper to taste; add boiling water as necessary.
3. When meat is nearly tender, combine flour with enough cold water to make a smooth paste. Stir enough of this mixture into the stew to give desired thickness, and add some browning for color.
4. Half cover the pot and continue simmering until meat is done. Add whiskey or rum if desired. Serve in cups or bowls, very hot, with the bones.

Yield: 24 servings

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Outta the Pool!

On a September afternoon in Botswana's Chobe National Game Park, about fifteen bull elephants returned to their favorite water hole to discover some unwelcome occupants. A pride of lions had taken over the precious pool, which was rapidly drying into a mud wallow.

Between May and September, competition for water may become a matter of life and death on the African plains. Elephants, which each need at least twenty gallons daily, dig many of the water holes themselves. After sensing hidden moisture with their noses, they can excavate five to eight feet of dry earth using their tusks and trunk. For their role in creating water holes, as well as in clearing brush, elephants are considered "keystone" species—their activities alter the landscape, creating new niches that benefit many kinds of creatures.

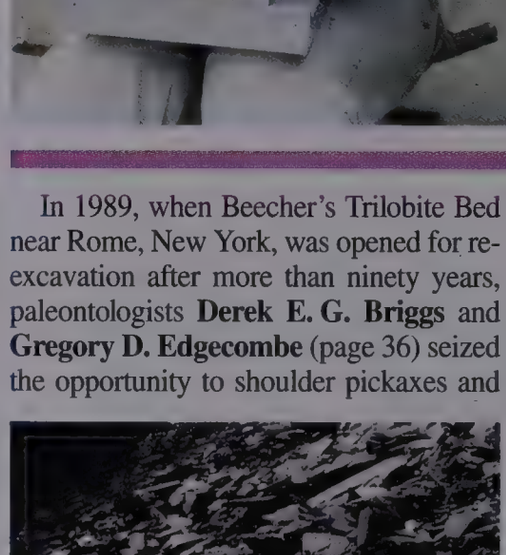
Although elephants usually avoid lions, especially when traveling with calves, this group of young bachelors had no hesitation about challenging the "king of beasts." One young bull fanned his ears, waved his trunk, and made straight for the big cats, which scattered in all directions. He and his group then settled in for an afternoon of guzzling, mud wallowing, and playful spritzing.

—Melissa Gedachian

Photograph by
Gregory G. Dimijian

Fishery biologist **Mikhail B. Skopets** (page 2) is shown here with a twenty-pound char he caught through the ice at Lake El'gygytgyn, in northeastern Siberia. Born in Ykaterinburg, the largest city in the Ural Mountains, Skopets comes from a family of musicians and physicians. As a boy, he loved game fishing and wilderness hiking and decided to make his hobby his profession. (As a naturalist, he says, he was "the black sheep" among his relatives.) After graduating from Ural University, Skopets joined the Institute for Biological Problems of the North in Magadan, Siberia, and earned an advanced degree in biological science from the Institute of Marine Biology in Vladivostok for his work on Siberian grayling. An interest in cold-water ecosystems and little-known areas of northeastern Asia led to his salmonid studies, including those in Lake El'gygytgyn.

In 1989, when Beecher's Trilobite Bed near Rome, New York, was opened for re-excavation after more than ninety years, paleontologists **Derek E. G. Briggs** and **Gregory D. Edgecombe** (page 36) seized the opportunity to shoulder pickaxes and prise bars in search of the quarry's unusua fossils, which are filled with pyrite, o fool's gold. After leaving their rock-break ing tools for the precision instruments o the lab, they analyzed the newly acquire fossils from different perspectives. Brigg (left), a reader in paleobiology at Eng land's University of Bristol, has long in vestigated exceptionally preserved fossil and what they can reveal of life's earl evolution. Among other projects, Briggs i studying the Hunsrück Slate of Germany the only other known instance of pyritiza tion on a par with Beecher's Bed. Edge combe (right), a postdoctoral researcher a the University of Alberta, in Edmonton Canada, is interested in the larval stages o trilobites and plans to study life historie and relationships of South American trilo bite families. Fossil fans can find mor information, and excellent pictures, i Riccardo Levi-Setti's *Trilobites: A Photo graphic Atlas* (Chicago: University o Chicago Press, 1975), and Niles El



A primary goal of their research, say **erese B. and John A. Hart** (page 28), is promote conservation of Zaire's Ituri orest. Terese and John met at Carleton ollege. Upon graduating, John went to e Ituri on a fellowship in 1973; the next ear Terese was a Peace Corps volunteer earby. After earning advanced degrees om Michigan State University in geog-phy and fisheries/wildlife (John) and en-omology and botany (Terese), the Harts eturned to the Ituri, where they have nce worked as associate research zoolo-ists with Wildlife Conservation Interna-onal, a division of the New York Zoolog-al Society. This May, Zaire designated ore than 5,000 square miles within the orest as an okapi reserve. The Harts' uggestions for reading include "The Re-tionship of the Okapi," by E. H. Colbert *Journal of Mammalogy* (vol. 19, no. 1, 938), and *Island Africa,* by Jonathan ingdon (Princeton: Princeton University ress, 1989).

redge's *Fossils: The Evolution and Ex-nction of Species* (New York: Abrams, 991). *Trilobites* by H. B. Whittington, a eading authority on these popular fossils, ill be published this fall (Rochester: oydell & Brewer, Inc.).

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Since the age of nine, when she lingered after drawing lessons at the Toledo Museum of Fine Arts to gaze at the Egyptian collections, **Barbara A. Worley** (page 54) has been intrigued by the cultures of the Sahara. Although she has never been camping in the United States, she has made three field trips to the central Sahara, sharing the nomadic ways of the tent-dwelling Tuareg for a total of almost four

years (the photo shows her, center, with members of the Kel Fadey tribe, including, to her right, Daguna, the late chief's eldest daughter). "Women's social prominence has a long tradition among the Tuareg, and the men take great pride in it," she says. "The Tuareg see their political identity as being closely tied to female origin myths and to wealth that once belonged to women." Worley received her doctorate from Columbia University and is currently a visiting scholar in the department of anthropology at Harvard University, where she is completing a book on Tuareg matrilineal kinship and gender ideology. For additional reading she recommends *People of the Veil,* by Francis Rennell Rodd (London: Macmillan, 1926); *Ecology and Culture of the Pastoral Tuareg,* by Johannes Nicolaisen (Copenhagen: National Museum, 1963); and *The Last Caravan,* by Thurston Clarke (New York: Putnam, 1978).

"Diving in the Antarctic is the closest thing on earth to walking in space," says **David G. Campbell** (page 46), a biologist with a doctorate in disease ecology from Johns Hopkins University. Growing up as far afield as Brazil and Kenya, he has continued to visit all corners of the earth in his research work—to date, 120 countries and all eight continents (Campbell declares that Antarctica is actually two continents fused by ice). A former director of the Bahamas National Trust, a research fellow at the New York Botanical Garden (where he conducted extensive ecological studies o Amazonian plant communities), and a re cipient of a Guggenheim Fellowship Campbell is currently Henry R. Luce Professor of Nations and the Global Environment at Grinnell College in Iowa. He i working on a book about Amazonian biodiversity. He and his wife, Karen Lowell, medicinal chemist, plan to spend part o next year as visiting professors at the University of Nanjing in China, where he wil teach biodiversity; she, natural product chemistry.

Gregory G. Dimijian (page 84), pictured above with his wife, Mary Beth, practices psychiatry in Dallas, Texas, and is an assistant professor of psychiatry at the University of Texas-Southwestern Medical School, where he also teaches a course in behavioral ecology. A dedicated wildlife photographer, Dimijian has traveled to eastern and western Africa, Costa Rica, Antarctica, Alaska, and Hawaii, as well as to coral reefs in the Philippines and Belize. This month's "Natural Moment" was taken while he was on an East African safari with his son David. To capture the elephant and lions on film, Dimijian used a Nikon F4 and a 300mm f2.8 Nikkor lens.

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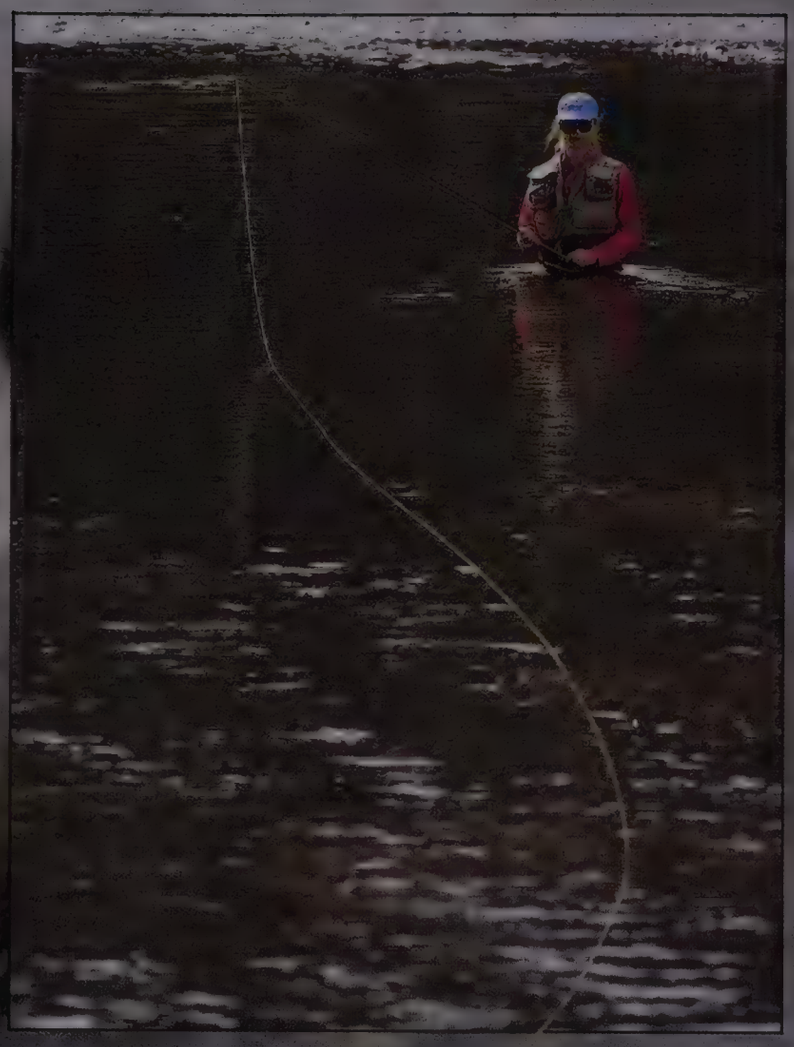

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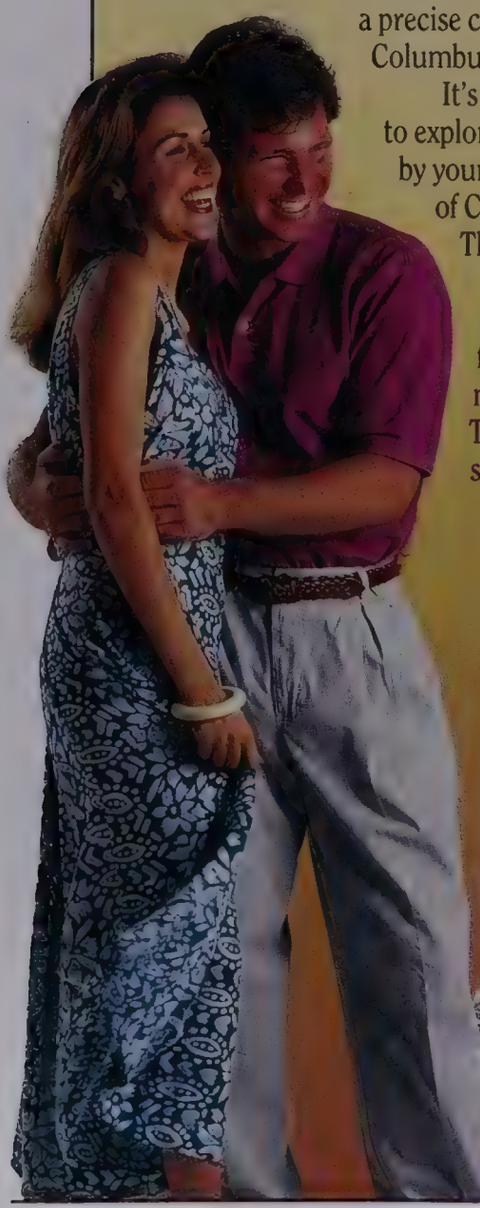

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VOL. 101, NO. 12, DECEMBER 1992

COVER: *An engraving by Maria Sibylla Merian (1647–1717) depicts a Caribbean rose's morning (white) and afternoon (red) phases on the same stalk, as well as the caterpillars that feed on the plant. Story on page 46. Illustration from the library of the American Museum of Natural History.*

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NATURAL HISTORY (ISSN 0028-0712) is published monthly by the American Museum of Natural History, Central Park West at 79th Street, New York, N.Y. 10024. Subscriptions: $25.00 a year. In Canada and all other countries: $34.00 a year. Second-class postage paid at New York, N.Y. and at additional mailing offices. Copyright © 1992 by American Museum of Natural History. All rights reserved. No part of this periodical may be reproduced without written consent of Natural History. Send subscription orders and undeliverable copies to the address below. Membership and subscription information: Write to address below or call (800) 234-5252 if urgent. Postmaster: Send address changes to Natural History, Post Office Box 5000, Harlan IA 51537-5000.

HOW MANY MOLECULES?

In "Oxygen, the Great Destroyer," by George Hendry (August 1992), the statement is made that "one molecule of oxygen readily combines with four molecules of hydrogen to form two molecules of water." Of course, it is two molecules—or four atoms—of hydrogen.

LOUIS P. PUSHKARSKY
Trenton, Missouri

Natural History regrets the error, which occurred in the editing process and is not the author's.

TWO SETS OF BROTHERS

In "Doctors of the Wilderness," by Anne LaBastille (May 1992), the caption over the painting on page 45 is incomplete. Although I do not recall the exact year, I remember well my father working on this painting some time in the 1960s. He worked from a photograph that *may* have been taken in 1914. It is not of the Sabattis brothers, but of the Stanton brothers: on the far left is my mother's father, George B. Stanton; third from the right is his brother, Henry Stanton. Both were Adirondack guides. At the far right is Raymon Sabattis, son-in-law of George Stanton and also a guide.

MILDRED BURNS DECHENE
Long Lake, New York

The owners of the painting, right, report that a handwritten note by Fred Burns on the back of his painting lists not only the Stanton brothers but also Raymon and Joseph Sabattis, as well as two other men, Everet Boyden and Claude Towns. The painting is dated 1960 and was based on a 1914 photograph.—Ed.

MUST WE SHOOT DEER?

Congratulations on Jared Diamond's "Must We Shoot Deer to Save Nature?" (August 1992). No doubt, an organization such as the American Museum is subjected to a tremendous amount of political pressure to ignore the facts of game management. Thanks for sticking to science, and not politics.

BRUCE J. MINCHER
Shelley, Idaho

Thank you for "Must We Shoot Deer to Save Nature?" It presented one of the mos thoughtful explanations of the subject tha I have read. Like it or not, humans hav caused this situation. By eliminating th larger predators, and failing to take ove their role, we are endangering the remain ing prey species.

CARL A. ZEH
Morrisonville, New Yor

It seems strange that we in the Omah area get so excited when someone come from another state and tells us how ou small wilderness area is on the brink o some terrible calamity and how, after al these years of a gentle, hands-off policy we need to exert the "man's control ove nature" policy. At the time of Diamond' visit, Fontenelle Forest had just com through a five-year drought and two year of late-spring freezes and was still thriv ing. If Diamond had checked, he woul have seen that it was frost-kill, not deer that caused the lack of acorns and hickory nuts in the forest, as well as the loss o many fruits across the midlands.

Diamond said we have only white

ke root and nettles in August. That is ause these are the wildflowers that are n in the late summer forest. Our other dflowers have bloomed, gone to seed, l disappeared until next spring. The ggestion to cut out old trees to make m for more vegetation would only in- ase deer habitat and consequently deer mbers. Old trees will fall in their own e and open the canopy. Experienced ers say that they see plenty of new s, hickories, and other tree seedlings the forest floor this year to replace the l ones. When Diamond described lings only of ironwood and hackberry, he realize that what looks like an iron- od sapling can actually be a forty- to y-year-old tree? They grow in the un- story naturally and are not a pioneer e in a disturbed environment.

We are not destroying the forest by ving it alone. The problem may be the reme impatience of people who do not ve time to let nature work things out in own way. The deer are not starving— y will increase or decrease in number urally, according to the varying condition of their habitat. The trees are not dying out—the forest is dynamic and continually undergoing change.

ELAINE SABIN
Bellevue, Nebraska

JARED DIAMOND REPLIES:

I wish I had the power to convince excited readers in other states how to manage their wilderness areas. Actually, it was the Fontenelle Forest Association itself that recently decided to develop an active management plan, and to stop pretending that nature was working without interference at Fontenelle. That decision was based on years of study by Association members and staff. They have no problem telling the difference between young and old ironwoods, noticing what flowers are or are not blooming each month, and realizing that failure of oak and hickory regeneration predates the past five years. The area has become a virtual deer park in which the beautiful climax forest that Ms. Sabin admires is being replaced by deer-proof vegetation—not "the right stage," in the Association's opinion.

Anne LaBastille; Courtesy of Mr. and Mrs. John Hossley

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Columbus Cracks an Egg

Was the great voyager also a heavy-handed trickster?

by Stephen Jay Gould

The moment of truth—put up or shut up—has arrived. It is September, and this column has a lead time of three months. I either write about Christopher Columbus now or I miss the opportunity to note the most important quincentennial of my lifetime. Five hundred one just doesn't have that nice, even ring that we associate with celebrations.

Obviously, since I have delayed to the last possible moment, I have experienced no burning desire to address this subject. My reluctance does not arise from any doubt about the importance of the event, or of its relevance to natural history, but only from a widely shared feeling of personal ambivalence toward the value and meaning of Columbus's Bahamian landfall. History is full of horror, and we prefer to commemorate rare moments of light. I did not note, in 1983, the 500th anniversary of Torquemada's leadership of the Spanish Inquisition, so why should I celebrate, nine years later, an expedition that led to even more bloodshed and chauvinism (and was, incidentally, not unrelated to Torquemada's success)?

I am scarcely alone in my ambivalence, and this greatest opportunity for a white man's patriotic outburst has been a muted thing indeed. The usual, and entirely valid, reason for subdued acknowledgment arises from the treatment of indigenous peoples by their European conquerors—a panoply ranging from enslavement to genocide, with occasional islands of decency. For a natural historian, the further theme of environmental rape and pillage only adds to the profound feeling of ambiguity. While fully allying myself with these reasons for doubt, I would rather emphasize another set of home-grown factors, all too rarely discussed (and often not even mentioned) in popular statements of reluctance to celebrate.

Fourteen hundred ninety-two was an amazing year in Spain, a moment of triple coincidence. We may now be marking Columbus's quincentenary, but 1992 is also the 500th anniversary of military victory over the Moors and of the expulsion of all Jews from Spain—and the three events are complexly intertwined, for this is a causal coincidence, not a fortuitous array of simultaneous happenings. Moreover, Columbus's expedition ranks last in time among the three, and was partly a consequence of the other two, not a prod.

The marriage, in 1469, of Ferdinand of Aragon (roughly east Spain) and Isabella of Castile (roughly west Spain) began a train of events that led to both increased power and, in a term now tragically in vogue, to "ethnic purification" for a white and Catholic Spain. Isabella's victory in her war of succession against Afonso V of Portugal, and Ferdinand's accession to the throne of Aragon, following the death of his father, John II, in 1479, established a powerful joint monarchy, committed to the expansion of power and territory and the contraction of the ethnic and religious diversity that had marked the Iberian peninsula for centuries.

The Encyclopædia Britannica's article on Spanish history notes: "With its large Moorish and Jewish populations, medieval Spain was the only multiracial and multireligious country in Western Europe, and much of the development of Spanish civilization in religion, literature, art, and architecture during the later Middle Ages stemmed from this fact" (quoted from the 1980 edition, before contemporary terminology of "political correctness" came into vogue—so don't blame this claim on early 1990s fashion).

But the *reyes catolicos* (the Catholic kings), as Ferdinand and Isabella were called, struggled to terminate this diversity and succeeded in the Columbian year of 1492. The campaign against the Moors who had held power for nearly 800 years and had once ruled almost all of Spain had been proceeding for centuries. The final conquest of Granada and its Alhambra, with the capitulation and exile of Boabdil, the last Muslim ruler, ended a long process of conquest and removed the last handhold of Islamic temporal power in Western Europe (although the Turks besieged Vienna in 1683). Aided greatly by internecine warfare within the Moorish ruling family, Ferdinand and Isabella prevailed and received the keys to Granada from Boabdil on January 2, 1492 (in medieval walled cities with gates, keys to towns were more than symbolic). According to legend, the weak ruler (derisively called *el rey chico,* or "the little king," by the Spaniards) took one last look over his shoulder and burst into tears as he departed into exile. His powerful mother responded with the most viciously sexist one-liner in history: "Cry like a woman for what you could not hold as a man."

As for the Jews, Ferdinand and Isabella had obtained a papal bull from Sixtus IV for setting up an Inquisition in 1478. (Sixtus later regretted his decision when he understood the ferocity of the institution he had permitted and the ecclesiastical powers that he had given away.) The Inquisition itself—and this is widely misunderstood today—did not persecute professing Jews because it was established to root out heresy *within* Catholicism. Its ardor turned instead to the so-called *conversos,* or Jewish converts to Catholicism, whose successes and large numbers (some 300,000) had frightened the older establishment. In a mixture of paranoia and expediency (for the property of those convicted was confiscated and redistributed), the inquisitors searched for "Judaizing practices" among

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"I think Bob is on steroids."

the *conversos* as signs of their insincerity and their conspiracy to usurp the church from within. They used a variety of techniques that became a textbook for such later organizations as the S.S. and K.G.B., including networks of informers (who looked for such signs as failure of *converso* neighbors to buy adequate amounts of pork, or lack of chimney smoke emerging on Saturdays), interrogation with no right to counsel and no opportunity to confront hostile witnesses, and of course, torture and burning.

But when Tomás de Torquemada (ironically, from a *converso* family himself) became head of the Inquisition in 1483, he began to badger Ferdinand and Isabella about the professing Jews (who may have numbered close to 200,000). As this well- and long-established community retained such a focal role in arts and commerce, the monarchs were at first reluctant to follow Torquemada's advice. But their growing power and success, particularly in victory over the Moors, boosted their confidence and their narrow piety, and they issued an order for the expulsion of all Jews in t same focal year of 1492. Thus began t diaspora of the Sephardic (Spanish) Jew first largely into Portugal (where mar were killed or forcibly converted in 149 and thence to more accepting Musli countries (where many still live today, at least until recent migration to Israel and to a few pockets of relative toleratio in Europe, notably the Netherlands wher among many others of note, the gre philosopher Spinoza lived and worked.

A few days after the final departure the Jews in July, Columbus set sail on Au gust 3. I do not, of course, claim that th eventual, crucial patronage of Ferdinan and Isabella (after so much dithering ov so many years) arose directly from the "cleansing" of both Muslim and Jew fro their lands, but these prior events of 149 surely set a climate of narrow piety an aggressive expansionism that greatl boosted support for Columbus's plans. any case, I cannot, both as a Jew and as general celebrator of diversity and its cu tural benefits, view Spain in 1492 as a object of wholehearted commemoration.

And yet, I really don't want to bypas something so important by an almost cow ardly silence. I therefore take recourse i

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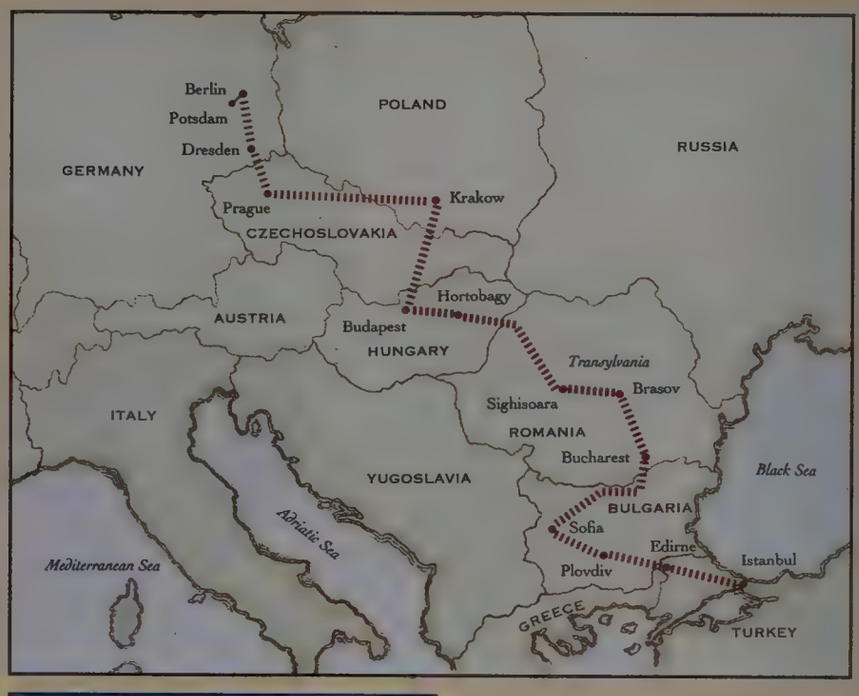

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vo of my own traditions. If I cannot cele-
ate the broad generality, let me look for
tiny little something about Columbus
vhich may then cascade by implication
a statement of wider worth), and let me
, once again, to my intellectual hero
harles Darwin for inspiration.

In his autobiography, Darwin writes
out his excitement in formulating the
inciple of natural selection as a young
an in 1838. But he then chides himself
r having ignored a crucial problem that
y evolutionary theory must resolve (we
ill return to the nature and identification
this problem at the end). Darwin writes:

ut at that time I overlooked one problem of
eat importance; and it is astonishing to
e, except on the principle of Columbus
d his egg, how I could have overlooked it
d its solution.

Now this is a famous quotation in the
arwinian brotherhood; it is cited over
d over again, and I have been encoun-
ring it throughout my professional life in
umerous guises. But something about
is statement always bothered me: I didn't
nderstand the reference to Columbus and
is egg—and no one ever bothered to ex-
lain it by commentary or footnote. As a
oung man, and with the usual diffidence
f those years, I hypothesized my own stu-
idity and shut up. That is, I assumed that
veryone else grasped something I ought
o know, and that one day I'd figure it out.
etter not embarrass myself by asking. As
got older and learned the ways of the
orld, I realized that if I didn't compre-
end the line, maybe no one else did ei-
ner—and the fact that every citationist
assed by Columbus's egg in silence could
ust as well signify ignorance as compre-
ension. Yet Darwin's mention is so off-
he-cuff that he, at least, must have re-
arded Columbus's egg as a schoolboy
ale known to all. But times change, and
he folk wisdom of one generation may be
blivion to the next. Will our children rel-
sh the details of Woody and Mia; do we
ven remember much about Joe DiMag-
io and Marilyn Monroe or Grace Kelly
nd the Prince of Monaco or Edward VIII
nd Ms. Simpson?

Cambridge, Massachusetts, is a funny
lace. The town is not so rarefied and intel-
ectual as some folks think, but it certainly
rovides a great advantage if you want to
ursue Columbus's egg by the art of sur-
ey. I began by asking several of my con-
emporaries, and not a soul had ever heard
f Columbus's egg. So I queried some
lder American colleagues on the theory
hat Darwin had cited a former school-
boy's tale, now extinct. None of them had a glimmer. As a last effort, I then approached some older colleagues who had spent their childhoods in prewar Europe, conjecturing that Darwin might have cited folk wisdom that never crossed the ocean. I finally got some return, but no solution. Two of my colleagues (neither English, but both continental) remembered such a story but could not recall the details.

So I gave up, and Columbus's egg remained in limbo for me—there are, after all, more important matters demanding attention during our short sojourn in this vale of tears. Then, as so often happens, the solution dropped into my lap when I wasn't looking. The scene switches to the spring equinox of 1989. The editorial and letters column of the *New York Times* are buzzing with an exchange about an old (and truly foolish) chestnut—the issue of whether or not one can balance an egg on its end during the equinoxes, but on no other day (now how many of you have encountered that one!). A Mr. Louis Marck—bless his soul—contributed the following letter on March 26, not only resolving Columbus's egg, but also acknowledging the failure of the story to penetrate our culture:

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In "It's Spring. Go Balance an Egg" (editorial March 19), you say that cheaters "crack the shell to create a flat bottom." According to a tradition strangely unknown in this country, one person who did that very thing, not as a cheater, but to prove a point, was Christopher Columbus.

My German dictionary of quotations places the apocryphal incident in 1493, at a banquet given in honor of Columbus by Cardinal Mendoza. When the difficulty of his voyage of discovery was put into question, Columbus challenged his interlocutors to balance an egg. When they failed, he did it by cracking the shell.

In German, as well as Spanish, "the egg of Columbus" has become proverbial for solving a difficult problem by a surprisingly simple knack or expedient.

Fine. A welcome solution. But why have I chosen this obscure item of Columbiana for my essay on this quincentenary? I may not particularly like the man, and I may feel nothing but ambivalence in contemplating his achievements, but I am both too vain and too conscious of duty to blow an essay by mock celebration of a triviality. The image is as colorful as the expression is clichéd: I will not cut off my nose to spite my face. No, I actively like the story of Columbus's egg and find it wonderfully illustrative of an important principle of science and intellectual life in general. Columbus's egg is an emblem for a different kind of ambiguity that we all must face.

Did Columbus achieve a fair solution of the puzzle that he himself had set? He asks his dinner companions to balance an egg. They assume that they may not destroy the object as they attempt to stand it on an end—and they fail as the egg rolls back each time. Columbus cracks the shell at its bottom, and the egg stands. I'm sure that he fractured the shell ever so gently—just enough to achieve a sufficiently flat bottom. But he still destroyed the egg. Does the destruction of an object count as a fair solution to a puzzle posed about it? Were Columbus's dinner guests unoriginal, obtuse, or bovine—or were they just properly respectful? And does such respectfulness always indicate a hidebound resistance to innovation?

The story of Columbus's egg is, of course, a metaphor about creativity and its meaning. Any true creator must wield a mallet against an accepted framework. The word *iconoclast,* after all, means "image breaker." We reserve the primary niches in our intellectual pantheon for great iconoclasts: For Galileo, fracturing a limited, earth-centered universe; for Darwin, shattering a system of created, immutable species. Our great intellectual revolutions are never simple infusions of knowledge into a previous void; they are always exercises in destruction and replacement.

But the dark figure, the fallen angel of mindless, truly anti-intellectual destruction always waits in the wings, carefully watching any potential episode of iconoclastic creativity, trying to impart the small nudge that pushes a potential intellectual triumph into the abyss of thoughtless destruction. The frenzied mob th cries for the blood of old privilege is better than the king's polite executione The rabble who cursed and spat Lavoisier on his way to the guillotin might just as well have been the henchme of Torquemada tightening the rack or th thumbscrews.

Consider the classical example of "clever" response that overstepped th boundary and substituted thoughtless de struction for genuine resolution—th story of Alexander and the Gordian kno In 333 B.C. after victories in Asia Mino and as he began a campaign that would de feat Darius and the Persian Empire Alexander marched to Gordium, the capital of Phrygia (now in central Turkey There he was shown the famous Gordia knot, an enormously complex configura tion (with a hidden end) that lashed th chariot of Gordius, ancient founder of th city, to a pole. According to legend, th man who untied the Gordian knot woul conquer all of Asia. Alexander took on look at the knot, drew out his sword, an cut it clean through. (If you don't like tale from antiquity, consider the best moder example from one of the Indiana Jone movies. Jones is challenged by a muscula local hero, who takes out his sword an puts on a long preliminary display b graceful and pyrotechnical brandishing o his preferred weapon. Jones withdraws hi gun and promptly plugs his adversary be tween the eyes.)

For that matter, I'm not so sure we should be celebrating the original iconoclasts by incorporating their name in such a favorable way into our language. The iconoclasts objected to veneration of icons or images of human faces, citing an interpretation of the biblical prohibition in the Ten Commandments against worshiping graven images (Traditional Islamic and Jewish religious art avoids images for the same reason.) The iconoclastic movement twice won power, only to be reversed within the Byzantine Empire during the eighth and ninth centuries. Ironically, the Christian art of Constantinople was ravaged twice—both times by Christians. First, by the iconoclasts during their temporary ascendancy; second, by the armies of the Fourth Crusade who, having failed in their objective of capturing Jerusalem, turned their marauding attention to Christians of another stripe. The Latin rulers of Byzantium (1204–1261) plundered the city, destroyed its art, and

n melted down most bronze statues for
n. When Mehmed II took Constantino-
for the Turks in 1453, he did not en-
ge in the wholesale destruction of
zantine art, which he admired. Islamic
rship precluded veneration of human
ures, so when many Christian churches
re converted to mosques, the great
zantine mosaics were often plastered
er, rather than ripped apart—and so,
nkfully, we may still enjoy them today,
restored in such shrines as Hagia
phia and the museum of the former
riye mosque (Saint Savior in Chora
der the Byzantines).

Alexander's assault upon the Gordian
ot remains one of the most ambiguous
ents in our history or legends. Some
ve praised Alexander, either for seeking
vel solutions apart from expected path-
ys or simply for taking decisive action
en the situation demanded an immedi-
response. But intellectuals have gener-
y read the story in a deeply negative
y, and I must align myself with my own
be in this case.

The quick and violent fix, particularly
e that destroys the very object that set
e puzzle, must be viewed as the antithe-
of our best mental functioning. I do not
y that all worthy intellectual activity
ust follow the silly stereotype of ponder-
s contemplation (the professor knitting
s brow and chewing on the end of his
asses). Brilliant insights are often the an-
nesis of calm and may be sudden or
en violent. But a revolutionary solution
a problem must at least honor the
ocesses of thought and not belittle our
entality for the sake of expediency.

At least I can document this negative
e of Alexander's example over several
nturies of commentary in my own field
geology. In 1690, Thomas Burnet called
r a naturalistic rather than a miraculous
terpretation of the Flood by attacking
ose who would simply attribute the ex-
ss water to God's creating power: "They
y in short, that God Almighty created
aters on purpose to make the deluge, and
en annihilated them again.... This is to
t the knot when we cannot loose it."
nd, in one of the most famous passages
all geological writing, Charles Lyell ex-
priated the miraclemongers with the
me image in 1833: "We see the ancient
irit of speculation revived, and a desire
anifested to cut, rather than patiently to
ntie, the Gordian knot."

Now I admit that cracking an egg at a
nquet may not be so drastic as severing
venerated object at the outset of a war.

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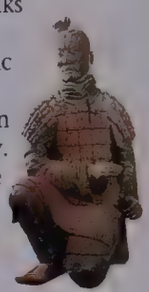

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But Columbus's solution still evokes the whiff of the philistine. Cracking the bottom was clever, but it violated the rules in a manner that strikes me as destructive of a legitimate game.

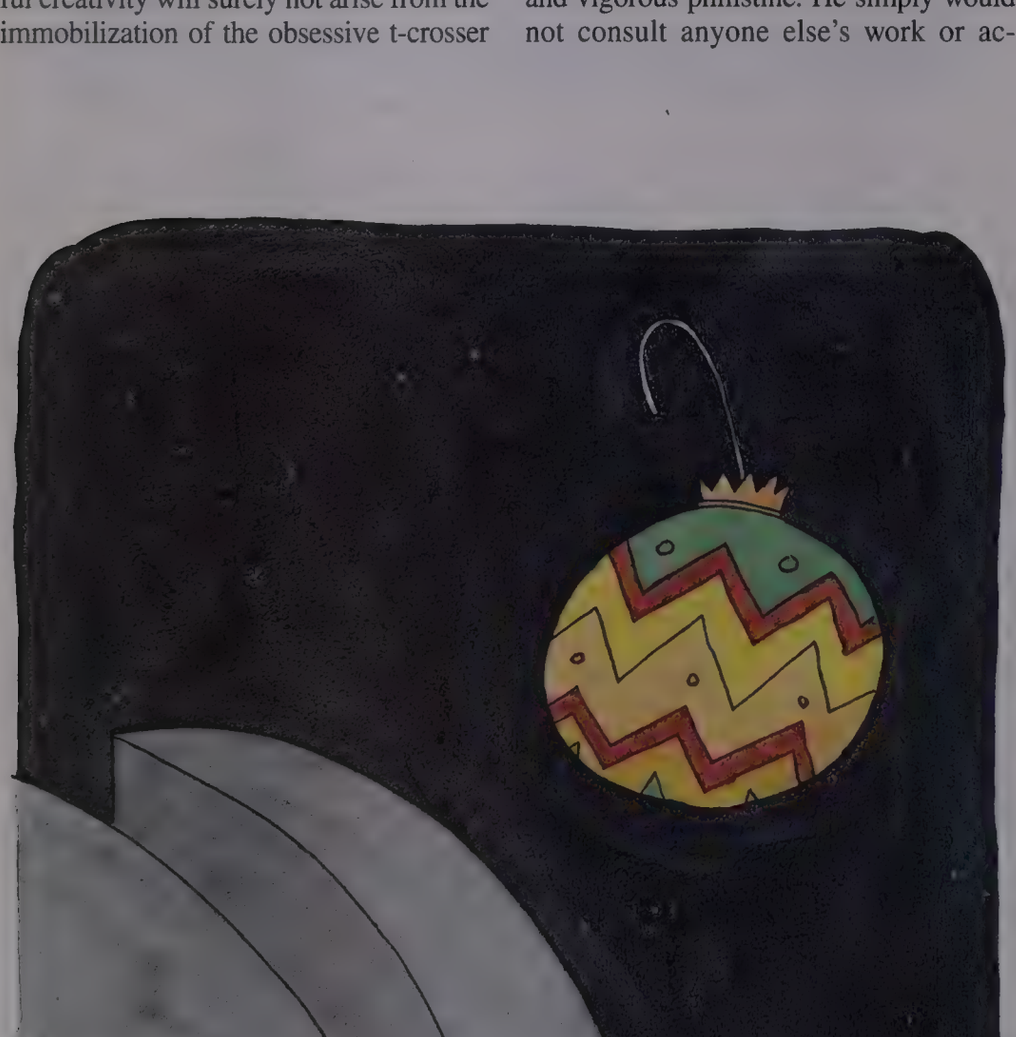
How then shall we define that most precious, yet most elusive, property called creativity? I don't know the answer of course. But we can at least state some properties and specify some criteria. The most historically potent and positive form of creativity must occupy the middle ground between strong respect for accepted norms and accumulated knowledge and Alexander's or Columbus's tactic of destroying rules and objects for an immediate and narrow victory. Maximally useful creativity will surely not arise from the immobilization of the obsessive t-crosser and i-dotter; but the waste and carelessness of a brilliant scholar who refuses to build upon the fruitful work of others, or even acknowledge past tradition (if only to break it), rarely yields much of use either. Let me tell one personal story about a man who, in my opinion, strayed too close to the Columbian end of this spectrum. Many people regard Richard Feynman as the greatest scientific genius of recent times. Perhaps so; as I said, I hardly know what the term means. But I do think that Feynman's antischolarly approach led him to waste a great deal of time, at the very least (and he died too young, with too much undone). Despite his stunning raw mental power, Feynman was a self-proclaimed and vigorous philistine. He simply would not consult anyone else's work or acknowledge that anything already in the lit erature might be worth his attention. He insisted on working everything out fo himself from first principles.

One may admire the audacity, but wha an inefficient system. The world, after all is not entirely inhabited by morons, and some conclusions of quality can be found in published sources. Several years ago, visited CalTech to give a lecture and spen the night in a suite that Einstein had occu pied. In the best conceivable follow-up my host told me the next morning tha Richard Feynman wanted to have breakfast with me because he had "figured ou some things about evolution" and wanted to discuss them with me (tell them at me would be more accurate, as it turned out). was delighted, of course, for I had never met the man and knew him only by his incandescent reputation. We sat for three hours, long past closing time for bacon and eggs. I was fascinated but also disturbed.

Feynman told me that he had reached some conclusions about evolution tha were probably important and no doub novel—all by reasoning from basic principles of Darwin's theory of natural selection. Well, he had figured out about half a dozen things, and they were all correct (so far as we know). But I was as dumbstruck as I have ever been in my intellectual life. Every one of his conclusions can be found in chapter one of any elementary evolution textbook. They were all figured ou more than a hundred years ago, mostly by Darwin himself. (Feynman, for example had rediscovered Darwin's principle o sexual selection in both versions of male combat and female choice.) I said to him "Dick, that's all well and true, but we really do know these things; they are the basis of our science; didn't you ever encounter them in your readings?" He replied that he had read nothing, on purpose.

Now Feynman could get away with such an antischolarly approach because he was so brilliant, and because the method had served him well. But he had frittered some time away in this case—and I would certainly not recommend this tactic to ordinary mortals, even highly intelligent and creative ones. My colleague Sid Coleman spoke of Feynman's willful ignorance of past work (quoted by James Gleick, *New York Times Magazine*, September 20 1992):

I'm sure Dick thought of that as a virtue, as noble. I don't think it's so. I think it's kidding yourself. Those other guys are not all a collection of yo-yos. Sometimes it would be



better to take the recent machinery they have built and not try to rebuild it, like reinventing the wheel. Dick could get away with a lot because he was so goddamn smart.

The intellectual version rarely produces real injury, and the cracked egg probably didn't spoil Cardinal Mendoza's dinner. But the destructive side of exploration can cause painful, palpable harm when the object involved is an inhabited land rather than an abstract concept.

I must recall the other column I once considered writing for the quincentenary. I wanted to illustrate the biological importance of taxonomic diversity by pointing out that I could personally solve the old debate about Columbus's Bahamian landfall if only he had collected a single *Cerion* shell (they live right at the coastline) as he stepped off the boat. Several islands have been proposed as the spot that Columbus called San Salvador; most historians accept Watling (now officially called San Salvador), but Cay Sal and several other spots have their defenders. *Cerion,* the focus of my personal research, is a highly diverse land snail with absolutely distinctive populations on each of the proposed islands. A single snail marked "This is the first thing I picked up when I landed on October 12, C. C." would settle the issue forever.

But then I thought, what irony! We know the distinctness of each island's *Cerion* because humans have never bothered them, and they have suffered no extinction or transportation. We have not disturbed these snails because they have absolutely no impact upon us: they are not agricultural pests and they taste terrible. They do not fight back; they cannot be enslaved; they know nothing of gold. But humans are exploitable, and their original Bahamian diversity was shattered in the wake of a man whom legend honored because he broke an object to illustrate his ability to manipulate it, and who sailed as emissary of a nation that had just purged the twin sources of its internal diversity.

Let us return then, in conclusion, to the subject of Darwin's attention when he cited the story of Columbus and his egg. What was the "one problem of great importance" that he had overlooked? Ironically again, Darwin identified the missing piece in his system as an explanation of *diversity.* Darwin realized that his original (1838) version of natural selection only told how one population might evolve into another of different form, but not how diversity might be produced—that is, how one population might branch into two descendants. He wrote, just after citing Columbus's egg: "The problem is the tendency in organic beings descended from the same stock to diverge in character as they become modified."

Darwin now understood that he would not have a complete theory until he could explain the origin of species, the process of making new twigs on life's bush—the source of the stunning variety that is both the glory and the staying power of life on earth. And so Darwin celebrated and sought to explain the very property that Spain had eliminated at home and Columbus diminished abroad—the diversity that is our ballast, our anchor, our only safe mooring in the flood of time. We either preserve this nurturing variety, or ultimately, we may intone a requiem for all humanity with Shakespeare's words for Hamlet (using a Columbian style of fracture): "Now cracks a noble heart. Good night, sweet prince."

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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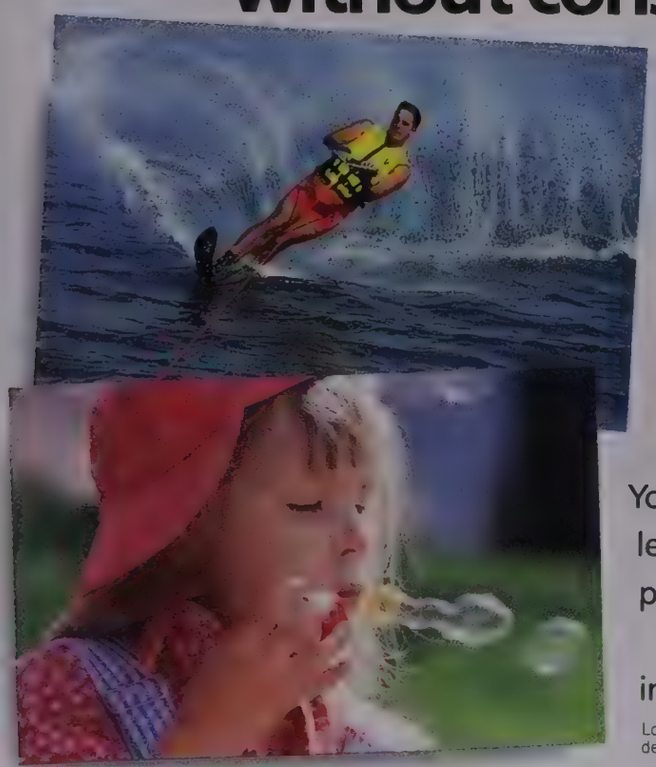

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Wet Watchers

There's a 90 percent chance you've heard this one before

by Roger L. Welsch

A few years ago I indulged my thirty-seventh mid-life crisis and attended a school for auto racing. We spent a day driving forward and backward, in circles and arcs, and then my instructor, Parker Johnstone, said, "Okay, Welsch, put it in reverse and go as fast as you can." One of the many things that crossed my mind on that occasion was that of all the millions of word combinations I had heard in my life, I had never heard that one. Now comes another one of those linguistic rarities, so listen closely: It's been a wet year here in Howard County, Nebraska.

Wet years don't happen very often on the edge of the sandhills—maybe every twenty or thirty years. We have cold winters and hot summers in just about equal balance, and as a result, America's principal agricultural product—tall tales—is also produced in roughly equal parts in regard to cold and hot. For every story about the day it was so cold that folks were going to church just to hear about hell, there is one about the day it was so hot, the farmers had to feed the chickens cracked ice so they wouldn't lay hard-boiled eggs.

But it doesn't work that way with precipitation: throughout most of my life, we've had one dry year, and then another dry year, and then another and another. The clear preponderance of the tall-tale inventory has run toward the arid: so dry that I saw a cottonwood tree following a dog; so dry that catfish came up from the river to get a drink at my pump; so dry that when a farmer in the field was struck by a raindrop, he fainted in astonishment, and to bring him around, his wife had to throw a bucket of dust in his face; so dry that this year Oak Creek ran only a half day a week. There just isn't equal opportunity to dust off (so to speak) the rainy weather tall-tale inventory.

Puffball mycelium will lie buried in the dust biding its time for years, I have been told, just waiting for an auspicious occasion to send its white balloons into the light, and tall tales must operate on pretty much the same survival strategy. We get a wet summer and all at once, everywhere you look you see puffballs and every conversation is seasoned with wet-weather stories.

Sure, almost every summer we get a gully washer or two, but on those occasions, humor focuses not so much on the season as on the event:

"I hear you got over twelve inches of rain last year?"

"Yep, and I felt lucky to be home that night, too."

"I don't know for sure how much rain we got last night, but a five-gallon bucket in my backyard was full up and would have been even fuller if it weren't for the two-inch hole in the bottom!"

Prairie deluges are often not only short in duration but limited in area. I was once driving on Interstate 80 and I could see clearly that it was raining across the median in the westbound lane while I was completely dry heading east. Storytellers have to go some to outdo reality. No thunderstorm season would be complete without someone telling about the time he was coming home from town with a team and wagon, spotted a cloudburst coming up behind him, made a mad dash for home, and arrived there dry as toast—only to

find that his poor dog had drowned in the back of the wagon.

That story usually initiates a series of efforts by other liars to recall even more spectacularly localized rains, like the milkmaid carrying two empty buckets, trying to outrun a Plains storm, and arriving at the barn with one bucket full of water and the other empty. Or my favorite, the hunter who leaned his double-barreled shotgun against a fence post as he crawled through, when a storm suddenly swept by, filling one barrel full of water but leaving the powder in the other absolutely dry.

Such brief cloudbursts are not grounds enough to say something as rash as, "It's been a wet year here in Howard County, Nebraska," or to open the floodgates for wet-weather lies. The point of rural folk humor remains the fickle nature of the rains: "Yep, best time to plant alfalfa is just before a two-inch rain." "Only rains twice in Nebraska—once too late for the wheat, once too late for the corn." "Dee Steffenhagen heard there was a 50 percent chance of rain this morning so she wore one overshoe to town." "When I was working construction, we used to call off work on account of rain when six raindrops hit one brick. Of course, sometimes we had to move that brick around a lot."

Then, about the first of July, when the rivers are still running full, frogs still singing at night, and puffballs flourishing, you begin to sense that the old-timers may just about be ready to declare it a wet year and break out the old classics no one has heard for so long. What a relief it was, for instance, that it only rained twice last week: once for three days and a second time for four. Or the most-beloved of rainy weather stories on the Plains, the one about the farmer who couldn't even get out his muddy lane for several months and finally had to walk into town just to get some basic supplies—flour, sugar, salt, news. About a mile out, he found his way blocked by a puddle that was more like a lake. He started to walk around that body of water and about halfway around, he spotted a real nice hat floating off shore. He reached out with his foot and kicked that hat closer so he could grab it, but imagine his shock when he found a head under the hat! "Are you okay, stranger?" the farmer gasped. "Well, I guess so," said the traveler. "I'm on horseback."

There are rumors about a farmer who had so much flooding in his pastures, he finally had to cut an opening in his barbed wire fence to let the water run out. And about harvesttime, stories drift in about farmers who, instead of pulling wagons to take the grain from their combines, are simply pulling barges along behind; about the guy who last year had his corn just dry up and fall off the stalk, only to find that this year the carp ate it off at the water line.

So often in today's America, orally transmitted stories grow like mushrooms, swelling into full maturity in a couple days and then disappearing. What happened to all the elephant riddles, light-bulb gags, Polish jokes, Zsa Zsa Gabor gibes? Gone. They were suddenly here and suddenly gone. (Mercifully, we can anticipate the same fate for blonde jokes.) On the rural Plains, wet-year knee slappers have a similarly brief moment of life, but when they're gone, they're not really gone. Like puffballs when drought returns, the mycelium of folklore is replanted in the minds of the next generation. Sooner or later, when the rains come and stay again, it will be my turn, or my daughter's, to say, "Yeah, I'm getting a little worried about all this rain. I hear that Gaylord Obermiller has been gathering animals over at his place, two by two."

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

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Dragons in Eden

by Matt Cartmill

"At last the Dodo said, '*Everybody* has won, and *all* must have prizes.' "
—Lewis Carroll

We can never find out all we would like to know about the distant past, and we always have to fill in missing information by extrapolating from the way things are today. As a result, we sometimes wind up imposing our own fears and fantasies on prehistory, like a paranoid seeing the faces of imaginary enemies in a Rorschach inkblot. And as different people see different things in the same inkblot, so different generations see the same past in different lights. These two handsomely illustrated books point to some striking differences between images of dinosaurs in the mid-1800s and the 1990s, which tell us at least as much about the differences between that time and this as they do about progress in paleontology.

Martin Rudwick's *Scenes from Deep Time* chronicles the early history of artists' conceptions of extinct creatures and the prehistoric landscapes they inhabited. The first published pictures of fossil animals on the hoof were simple outline drawings of Eocene mammals; they appeared in 1822 in the second edition of French naturalist Baron Georges Cuvier's book on fossil bones. Eight years later, the English geologist Sir Henry De la Beche ventured the first picture of a prehistoric landscape, based on marine fossils from Jurassic strata of southern England. De la Beche's picture of *Duria antiquior* (more ancient Dorset) shows an antediluvian world full of cheerful, incessant carnage, with ich-

Duria antiquior, *a depiction of prehistoric life, drawn about 1830 by Henry De la Beche and reproduced in* Scenes from Deep Time

Scenes from Deep Time

Early Pictorial Representations of the Prehistoric World

Martin J. S. Rudwick

With stunning rare illustrations and engaging commentary, Rudwick traces the nineteenth-century collaboration between scientists and artists that gave us our first images of dinosaurs and their environment.

"Primates are primarily visual animals—and how we reconstruct the history of life through drawings is the surest path to insight about our concepts and biases. Martin Rudwick virtually invented this important field of inquiry, and **this book is the finest ever written on this vital subject."—Stephen Jay Gould,** Harvard University

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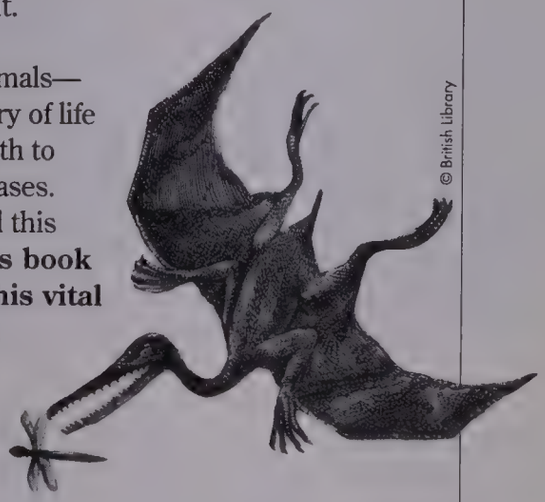

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nyosaurs crunching up fish, squid, and lesiosaurs while another plesiosaur in the ackground snatches a screeching ptero-actyl out of the air.

This sort of reconstruction is so familiar oday that it is hard for us to grasp what a eat of imagination it took to make that ump from fossil bones to images of living nonsters cavorting in a primeval land-cape. Surveying the history of such im-ges with an art historian's expert eye, udwick demonstrates De la Beche's orig-nality by showing how much everybody lse borrowed from *Duria antiquior*. Fig-res and motifs from De la Beche's pic-ure—those ammonites decked out with ails like the fabled nautilus, that ichthyo-aur clutching a plesiosaur's serpentine

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INOTOPIA, by James Gurney. *Turner Pub-shing, Inc., $29.95; 160 pp., illus.*
CENES FROM DEEP TIME: EARLY PICTOR-L REPRESENTATIONS OF THE PREHISTORIC ORLD, by Martin J. S. Rudwick. *The niversity of Chicago Press, $45; 296 pp., lus.*

---

eck in its crocodilelike jaws, those pte-saurs hanging flat and motionless in the y as though they were nailed to it—kept n appearing in books and prints by Eng-sh, French, and German geologists for ecades afterward.

Once De la Beche set the example, pre-storic landscapes swiftly became an es-blished genre of scientific artwork, at-acting better artists with newer ideas. ohn Martin's mezzotints of hideous imeval monsters battling by moonlight ere especially popular with Gothic-inded Victorians. Mesozoic scenes egan to appear in cheap, mass-circulation agazines in 1833. The first children's ook on dinosaurs came out in 1837. In 349, John Emslie hit on the idea of de-

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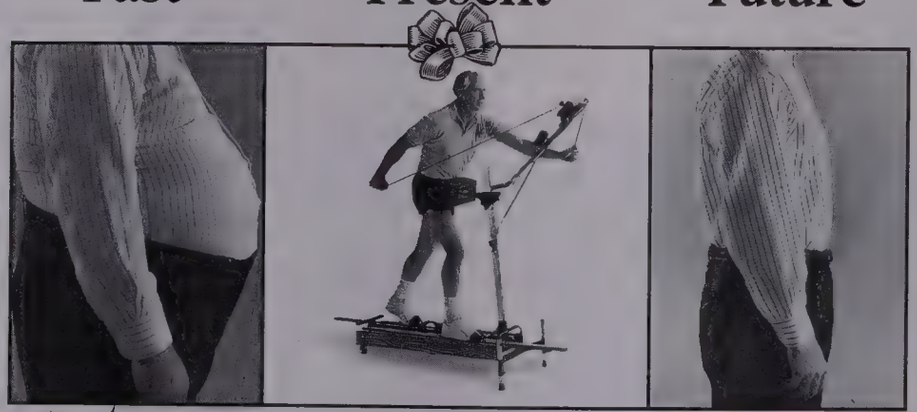

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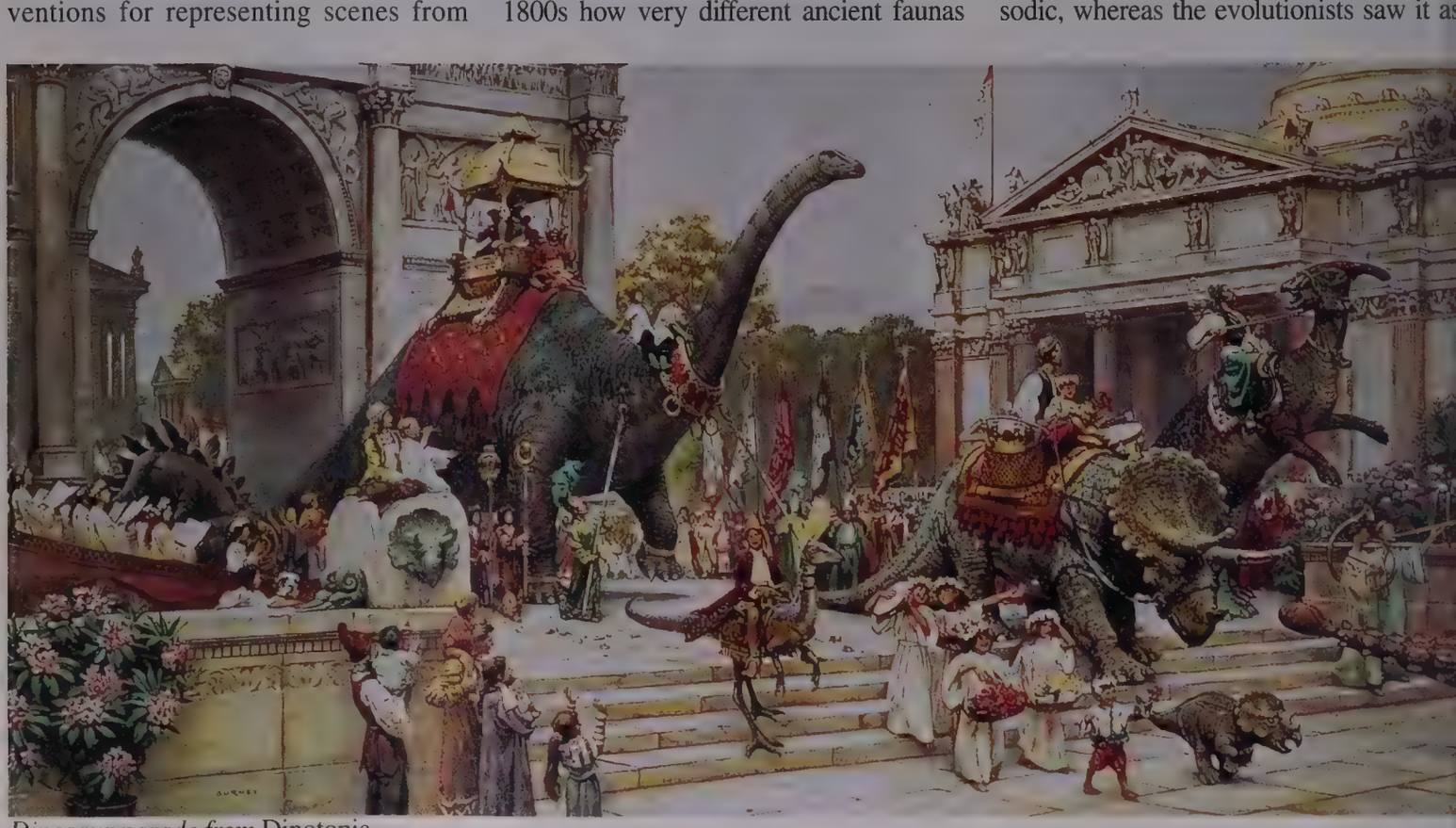
Boulevard scene from James Gurney's Dinotopia

picting geological time as a spatial vector within a single panorama, in which primitive ancestors at one end are gradually replaced by more advanced descendants as you move toward the other end. Emslie's image of the geological record as a march of progress took sculptural form in 1854 when a procession of full-sized concrete statues of ancient amphibians and reptiles arranged in chronological order went on display at London's Crystal Palace. By the early 1860s, virtually all the modern conventions for representing scenes from deep time were in place, along with the theoretical Darwinian machinery for explaining the march of prehistory, and here Rudwick brings his story to a close.

If European science popularizers of the midnineteenth century put so much ingenuity and enthusiasm into the reconstruction of prehistoric landscapes, why didn't they get started until the 1830s, long after the scientific study of fossils had gotten under way? One reason, which Rudwick notes, is that it was not clear until the early 1800s how very different ancient faunas and floras were from those of modern times. But I suspect that there was more to it than that. The differences between our world and the lost worlds of the distant past had to be given some sort of meaning before they could attract the imaginations of artists and the public. Those differences became meaningful only after Cuvier, Lamarck, and others came up with ways of seeing geology and prehistory as a story with an edifying moral. Cuvier and his followers saw that story as jerky and episodic, whereas the evolutionists saw it as



Dinosaur parade from Dinotopia

smooth; but all parties agreed that it was the story of man's progress toward civilization, and that it had a happy ending and a gratifying moral punchline. Because the dinosaurs were savage, backward, and ugly, they had been supplanted by more advanced forms of life—just as, say, the backward savages of America, Africa, and Australia were being pushed out and replaced by civilized white people. Prehistoric narratives became interesting, and scenes from deep time became imaginatively compelling, only after they had acquired this underlying moral: in the end, savages are losers.

That moral is obvious in many of the nineteenth-century pictures and captions that Rudwick reproduces, which stress the ugliness and ferocity of the doomed prehistoric monsters and the gloominess of their world. "Looking back retrospectively ar over the wintry Ocean, into Pre-Adamic Shades," wrote one science popularizer in 1840, "we encounter execrable nd dreary things in the abounding Chaos." Another declared, "All that survives of these once-grim and omnipotent borigines are a few crushed bones as unsightly as they are rare." A similar contempt for our own ancestors, plainly nked to imperialist contempt for the conuered races, is evident in one of the very rst reconstructions of the evolutionary nk between ape and man, which Rudvick reprints from an 1861 pop-science ook by the French Darwinian Pierre oitard. Boitard's text describes his imagary ape-man as a "singular and horrible" nimal resembling a "squat and thickly uscular" orangutan. His illustration nows the creature as a well-built, hairy ack man with a simian head and feet and ick Negroid lips, clad in a dashing fur ape and brandishing an Iroquois tomawk.

Western convictions about historical rogress and the superiority of European vilization are not so firm nowadays as ey were in 1861. Many intellectuals day find the whole concept of progress uaint and disreputable and reject the non that history's losers deserved to lose. he current fashion is to think of losers as agic victims of circumstances beyond eir control. Interestingly, our ideas about nosaurs have been changing to correond to the new fashion. Dinosaurs, paletologists increasingly assure us, were t sluggish, brainless reptilian monstrosis but warm, nimble, sensitive, birdlike eatures with large brains and high metalic rates, which would still be ruling the earth if an unlucky asteroid impact hadn't brought them to an untimely and undeserved end 65 million years ago.

This new image of the dinosaurs is the point of departure for James Gurney's *Dinotopia,* a juvenile picture book that tells the story of a Victorian adventurer and his twelve-year-old son cast up by shipwreck on the shores of a large, unknown island. The island turns out to be inhabited by human castaways of all races and nationalities, coexisting in multicultural peace and harmony with each other and with dozens of species of intelligent, reasoning dinosaurs that have survived on the island since the Mesozoic. The book is illustrated with nearly two hundred paintings depicting the dinosaur-human civilization. All these lovingly imagined and elegantly rendered pictures, which look like stills from a hundred-million-dollar Lucasfilm travelogue about Munchkin Land, give the book a lot of charm and are sure to appeal to its younger readers.

Unfortunately, Gurney is not nearly as good a writer as he is an artist. His Victorian narrator writes imitation nineteenth-century prose except when he forgets, which he does all the time, so he sounds like Martin Van Buren in one paragraph and Abigail Van Buren in the next. The story he tells about all the marvels he encounters is a rambling traveler's tale, with little plot or point to it. The book's real point is all the emerald green ecopieties that make up the religion of this saurian Oz. In Dinotopia, universal peace and harmony prevail. All animals are equal, including the human ones. All species treat one another with courtesy and respect, admire one another's distinctive arts and crafts, and help one another recycle manure and tend babies. (In Dinotopia, the small dinosaur known to science as *Oviraptor,* "egg-stealer," is rechristened *Ovinutrix,* "egg nurse," and works in a day-care center.) There is no population pressure, because dinosaurs lay only two or three eggs in a lifetime. All the heavy work is done by the larger dinosaurs, who are proud to employ their great strength to serve the common good. Everybody is a vegetarian, except for a few grumpy tyrannosaurs who live in the jungle by themselves and are fed pickled fish to keep them quiet. Nobody even fells timber; all the lumber comes from trees that have died of natural causes. Dangerous sports like mountain climbing provide an occasional jolt of adrenaline for the citizens of this sleepy Shangri-La, but the general tone of the local culture is acutely so-

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porific. The conventional greeting in Dinotopia is "Breathe deep, seek peace," which strikes me as a pretty good description of a yawn.

It is not easy to write interesting stories about Utopia. Most interesting stories have a moral of some sort, and it is hard to find a moral in a story where everybody is one of the good guys. The nineteenth-century writers and artists showcased by Rudwick sought the moral of the story in their ideas of historical progress and the struggle for existence. Intellectuals today are increasingly repelled by those old ideas, suspicious of stories with morals, and reluctant to judge one species, culture, or way of life as superior to any other. Our forebears wanted to see dinosaurs as creatures too stupid and primitive to survive under the scourge of nature's pitiless competition; we prefer to think of the dinosaurs and other losers as innocent victims of random accidents. This may be closer to the truth about the dinosaurs, but it makes for a boring narrative. And as scientists, at some point we have to ask ourselves: If all accounts of prehistory are ultimately pointless, and there are no general truths to be learned by working out the stories of the winners and losers, then why should we go on putting so much effort into gathering facts about the remote past? Unless some of history's victories and losses were merited and predictable—as the theory of natural selection implies—the story of who won and who lost is ultimately not very interesting as science, or even as storytelling.

Matt Cartmill is an anthropologist at Duke University. His book, Nature's Edge, *a history of ideas about hunting and human origins, will be published by Harvard University Press in 1993.*

L'HOMME FOSSILE.

"Fossil Man," from Pierre Boitard's Paris before Men *reproduced in* Scenes from Deep Time

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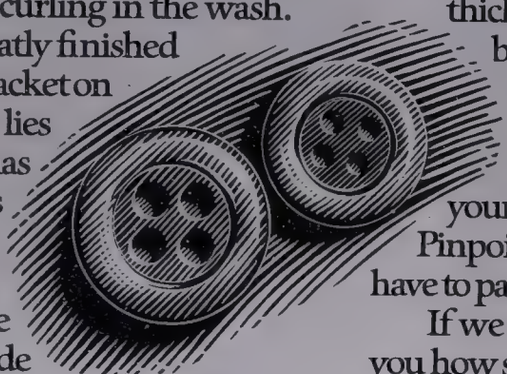

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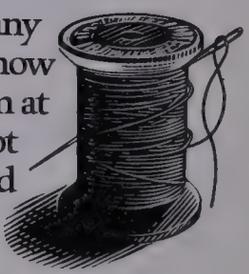

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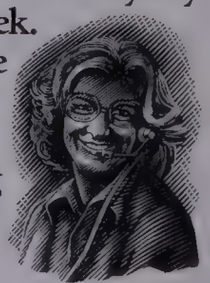

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The Emperor's Giraffe

Not every powerful country chooses world domination

by Samuel M. Wilson

A huge fleet left port in 1414 and sailed westward on a voyage of trade and exploration. The undertaking far surpassed anything Columbus, Isabella, and Ferdinand could have envisioned. The fleet included at least sixty-two massive trading galleons, any of which could have held Columbus's three small ships on its decks. The largest galleons were more than 400 feet long and 150 feet wide (the *Santa Maria,* Columbus's largest vessel, was about 90 by 30 feet), and each could carry about 1,500 tons (Columbus's ships combined could carry about 400 tons). More than one hundred smaller vessels accompanied the galleons. All told, 30,000 people went on the voyage, compared with Columbus's crew of 90-some.

The commander's name was Zheng He (Cheng Ho), the Grand Eunuch of the Three Treasures and the most acclaimed admiral of the Ming dynasty. He was sailing from the South China Sea across the Indian Ocean, heading for the Persian Gulf and Africa. As the historian Philip Snow notes in his wonderful book *The Star Raft* (1988), "Zheng He was the Chinese Columbus. He has become for China, as Columbus has for the West, the personification of maritime endeavour." The flotilla was called the star raft after the luminous presence of the emperor's ambassadors on board.

Zheng He did not really set out to explore unknown lands—neither did Columbus, for that matter—for the Chinese were aware of most of the countries surrounding the Indian Ocean. For centuries, China had been a principal producer and consumer of goods moving east and west from Mediterranean, African, and Middle Eastern trading centers. With this trade came cultural and ideological exchange. Zheng He, like many Chinese of his time, was a Muslim, and his father and his father before him had made the pilgrimage to Mecca. But in Zheng He's day, the trade routes were controlled by Arabian, Persian, and Indian merchants.

Private Chinese traders had been barred from traveling to the West for several centuries. China had been conquered by Genghis Khan and his descendants in the 1200s, and the Mongol emperors of the subsequent Yüan dynasty were the first to impose these constraints. In 1368 the Chinese expelled the Mongol rulers and established the Ming dynasty, which was destined to rule for the next 300 years. (Thus, in 1492 Columbus was searching for a "Gran Khan" who had been put out of business 124 years earlier.) After the period of Mongol rule, China became strongly isolationist, placing even more severe restrictions on Chinese traders.

In 1402 an outward-looking emperor named Yong'le (Yung-lo) came to power. Seeking to reassert a Chinese presence on the western seas and to enhance the prestige of his rule and dynasty, he began funding spectacular voyages by Zheng He. As sociologist Janet Abu-Lughod notes in *Before European Hegemony* (1989), "The impressive show of force that paraded around the Indian Ocean during the first three decades of the fifteenth century was intended to signal the 'barbarian nations' that China had reassumed her rightful place in the firmament of nations—had once again become the 'Middle Kingdom' of the world."

As Zheng He pressed westward in 1414, he sent part of the fleet north to Bengal, and there the Chinese travelers saw a wondrous creature. None like it had ever been seen in China, although it was not completely unheard of. In 1225 Zhao Rugua, a customs inspector at the city of Quanzhou, had recorded a secondhand description of such a beast in his strange and wonderful *Gazetteer of Foreigners.* He said it had a leopard's hide, a cow's hoofs, a ten-foot-tall body, and a nine-foot neck towering above that. He called it a *zula,* possibly a corruption of *zurafa,* the Arabic word for giraffe.

The giraffe the travelers saw in Bengal was already more than 5,000 miles from home. It had been brought there as a gift from the ruler of the prosperous African city-state of Malindi, one of several trading centers lining the east coast of Africa (Malindi is midway along modern Kenya's coast, three degrees south of the equator). Zheng He's diplomats persuaded the Bengal king to offer the animal as a gift to the Chinese emperor. They also persuaded the Malindi ambassadors to send home for another giraffe. When Zheng He returned to Beijing, he was able to present the emperor with two of the exotic beasts.

A pair of giraffes in Beijing in 1415 was well worth the cost of the expedition. In China they thought the giraffe (despite its having one horn too many) was a unicorn (*ch'i-lin*), whose arrival, according to Confucian tradition, meant that a sage of the utmost wisdom and benevolence was in their presence. It was a great gift, therefore, to bring to the ambitious ruler of a young dynasty. The giraffes were presented to the emperor Yong'le by exotic envoys from the kingdom of Malindi, whom the Chinese treated royally. They and their marvelous gift so excited China's curiosity about Africa that Zheng He sent

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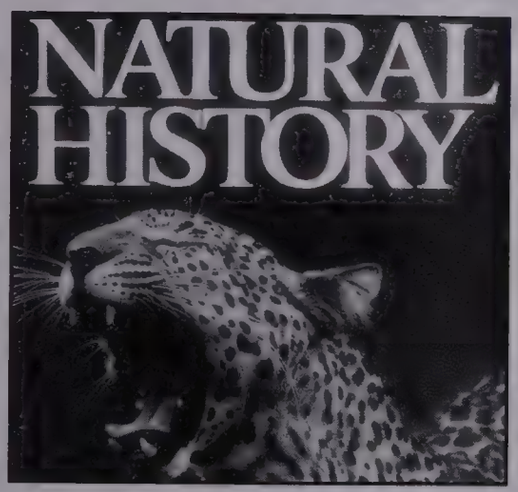

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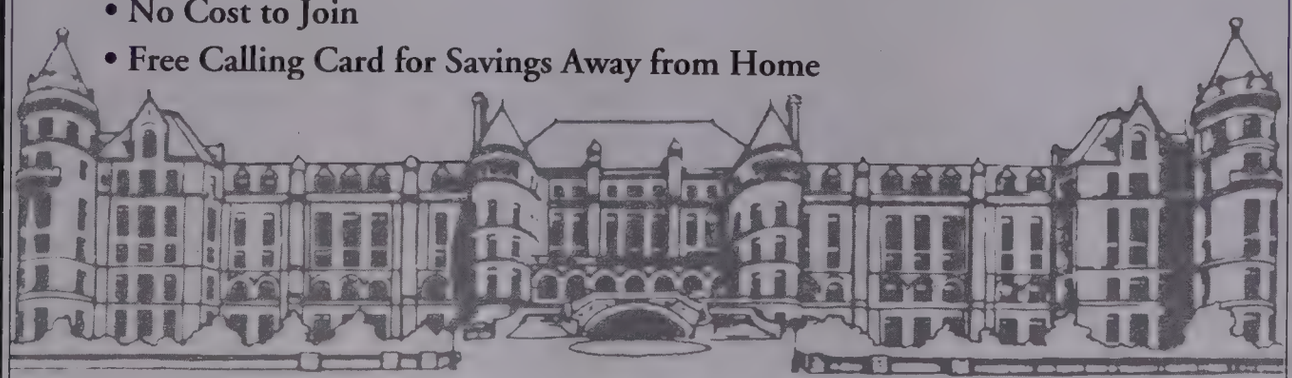

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Tribute Giraffe with Attendant, *an early fifteenth century painting on silk by Shen Tu*
Philadelphia Museum of Art: Gift of John T. Dorrance

word to the kingdom of Mogadishu (then one of the most powerful trading states in East Africa and now the capital of modern Somalia) and to other African states, inviting them to send ambassadors to the Ming emperor.

The response of the African rulers was overwhelmingly generous, for China and Africa had been distant trading partners from the time of the Han dynasty (206 B.C. to A.D. 220). In the *Universal Christian Topography,* written about A.D. 525 by Kosmas, a Byzantine monk known as the Indian Traveler, Sri Lanka is described as a trading center frequented by both Chinese and Africans. Envoys from a place called Zengdan—the name translates as "Land of Blacks"—visited China several times in the eleventh century. And a Chinese map compiled in the early fourteenth century shows Madagascar and the southern tip of Africa in remarkable detail, nearly two centuries before the Portuguese "discovered" the Cape of Good Hope. Archeologists find china (why the English word came to be synonymous with glazed pottery and porcelain, instead of silk or spices, is unclear) from the Han and later dynasties all along the east coast of Africa.

The African emissaries to the Ming throne came with fabulous gifts, including objects for which entrepreneurs had long before managed to create a market in the Far East—tortoise shell, elephant ivory, and rhinoceros-horn medicine. On their many visits they also brought zebras, ostriches, and other exotica. In return, the Ming court sent gold, spices, silk, and other presents. Zheng He was sent with his fleet of great ships on yet another voyage across the Indian Ocean to accompany some of the foreign emissaries home. This escort was the first of several imperially supported trips to Africa. According to official records, they went to Mogadishu, Brava, and perhaps Malindi; Snow (in *The*

Star Raft) suggests that these Chinese expeditions may have gone still farther—to Zanzibar, Madagascar, and southern Africa.

Meanwhile, as the Chinese were pushing down the east coast of Africa, Portuguese mariners were tentatively exploring the west coast. They had started the process in the early fifteenth century and were steadily working their way south. Bartolomeu Dias reached the Cape of Good Hope in 1488 and was the first of these mariners to see the Indian Ocean. Surely the Europeans and Chinese were poised to meet somewhere in southern Africa, where perhaps they would have set up trading depots for their mutual benefit.

This did not happen, however. Emperor Yong'le died in 1424, and by 1433 the Ming dynasty discontinued its efforts to secure tributary states and trading partners around the Indian Ocean. In Beijing, those favoring an isolationist foreign policy won out, and the massive funding needed to support Zheng He's fleet—difficult to sustain during what was a period of economic decline in China—was canceled. As Edwin Reischauer and John Fairbank note in *East Asia: The Great Tradition* (1960):

> The voyages must be regarded as a spectacular demonstration of the capacity of early Ming China for maritime expansion, made all the more dramatic by the fact that Chinese ideas of government and official policies were fundamentally indifferent, if not actually opposed, to such an expansion. This contrast between capacity and performance, as viewed in retrospect from the vantage point of our modern world of trade and overseas expansion, is truly striking.

The contrast also refutes the argument that as soon as a country possesses the technology of overseas trade and conquest it will use it. Zheng He's fleet was 250 times the size of Columbus's, and the Ming navy was many times larger and more powerful than the combined maritime strength of all of Europe. Yet China perceived her greatest challenges and opportunities to be internal ones, and Yong'le's overseas agenda was forgotten. Restrictions on private trade were reimposed, and commercial and military ventures in the Indian Ocean and South China Sea in subsequent centuries were dominated by the Portuguese, Arabs, Indians, Spaniards, Japanese, Dutch, British, and Americans. Zheng He's magnificent ships finally rotted at their moorings.

Samuel M. Wilson teaches anthropology at the University of Texas at Austin.

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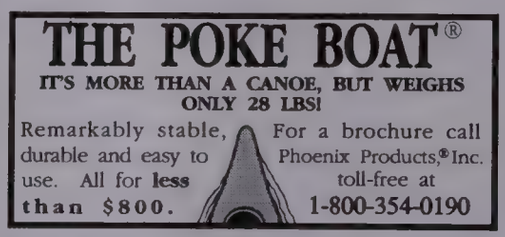
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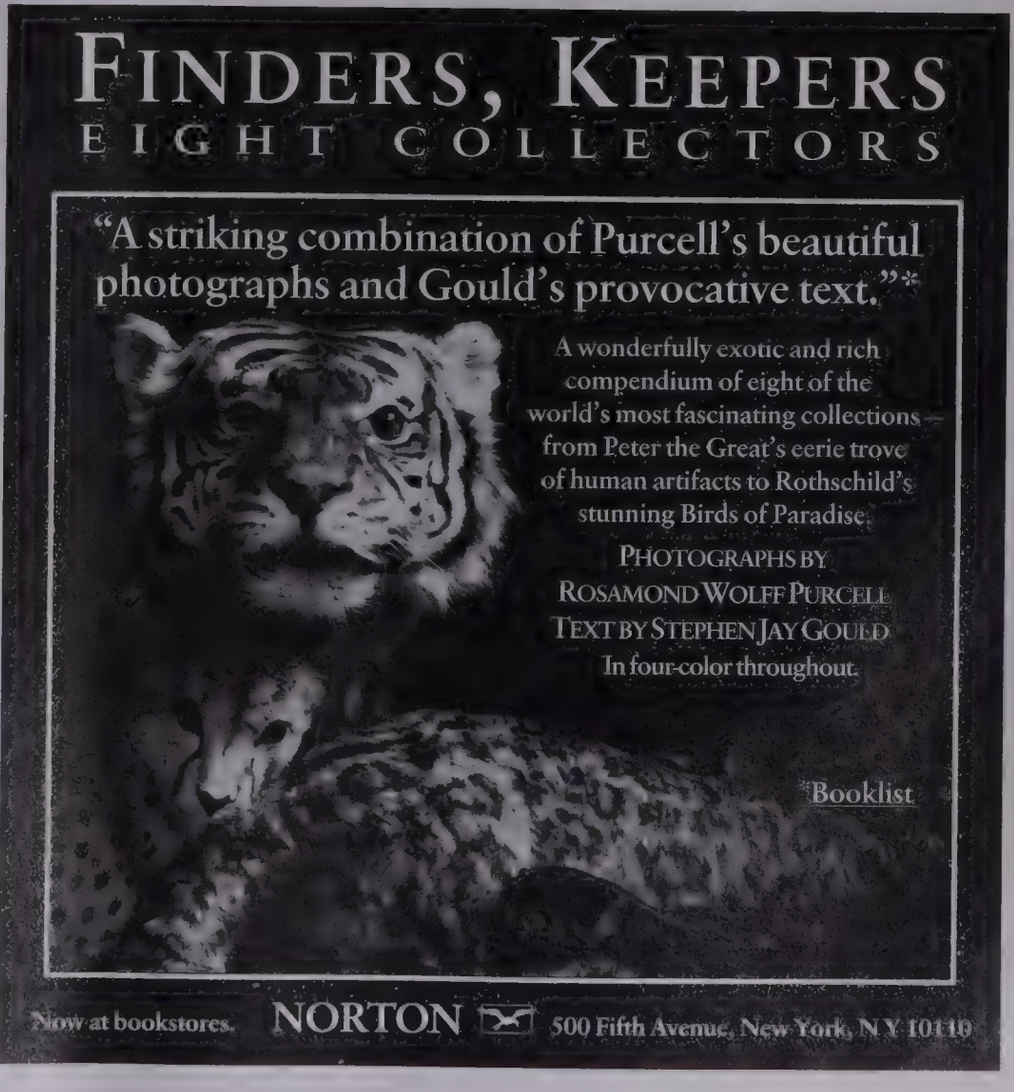
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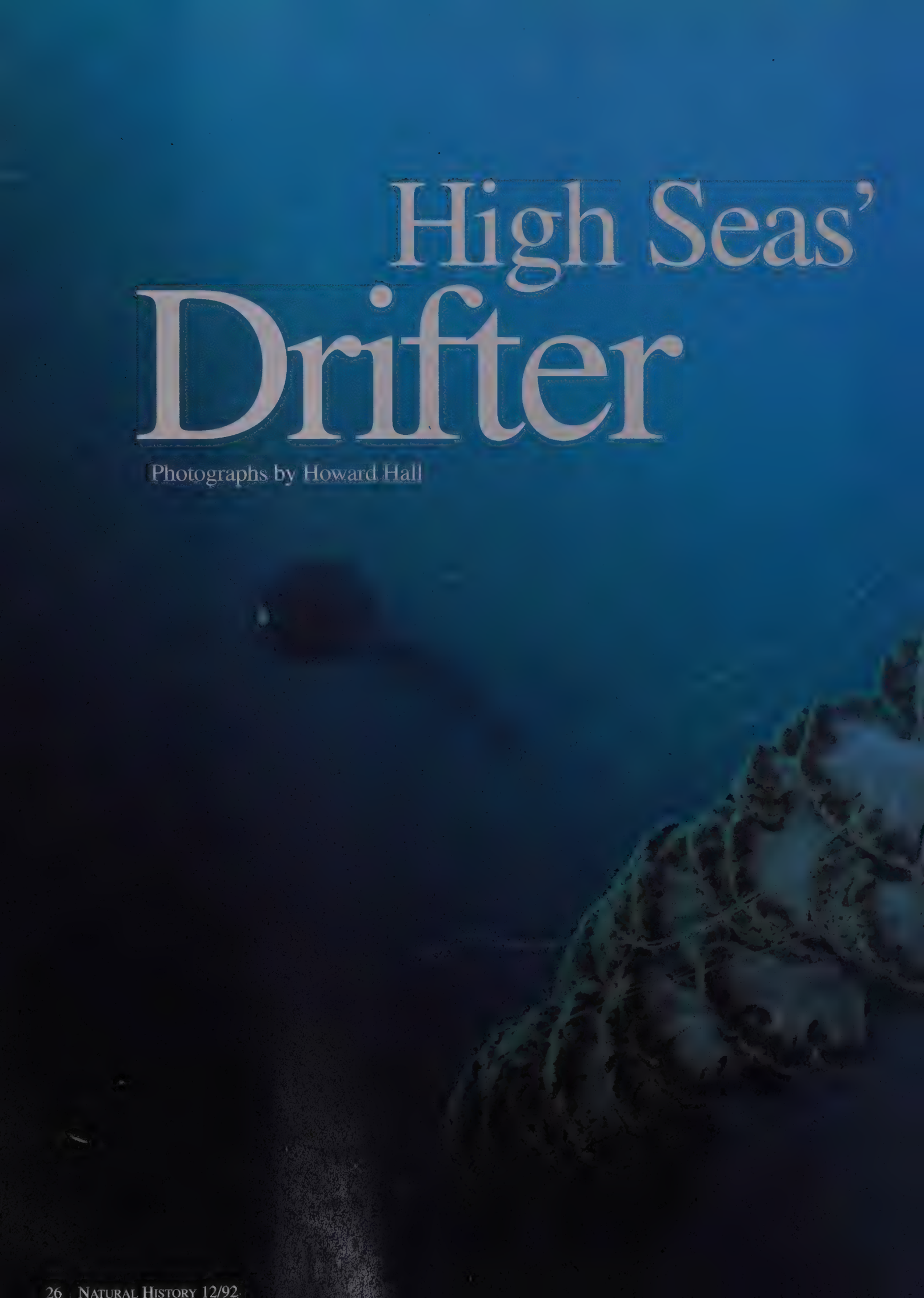
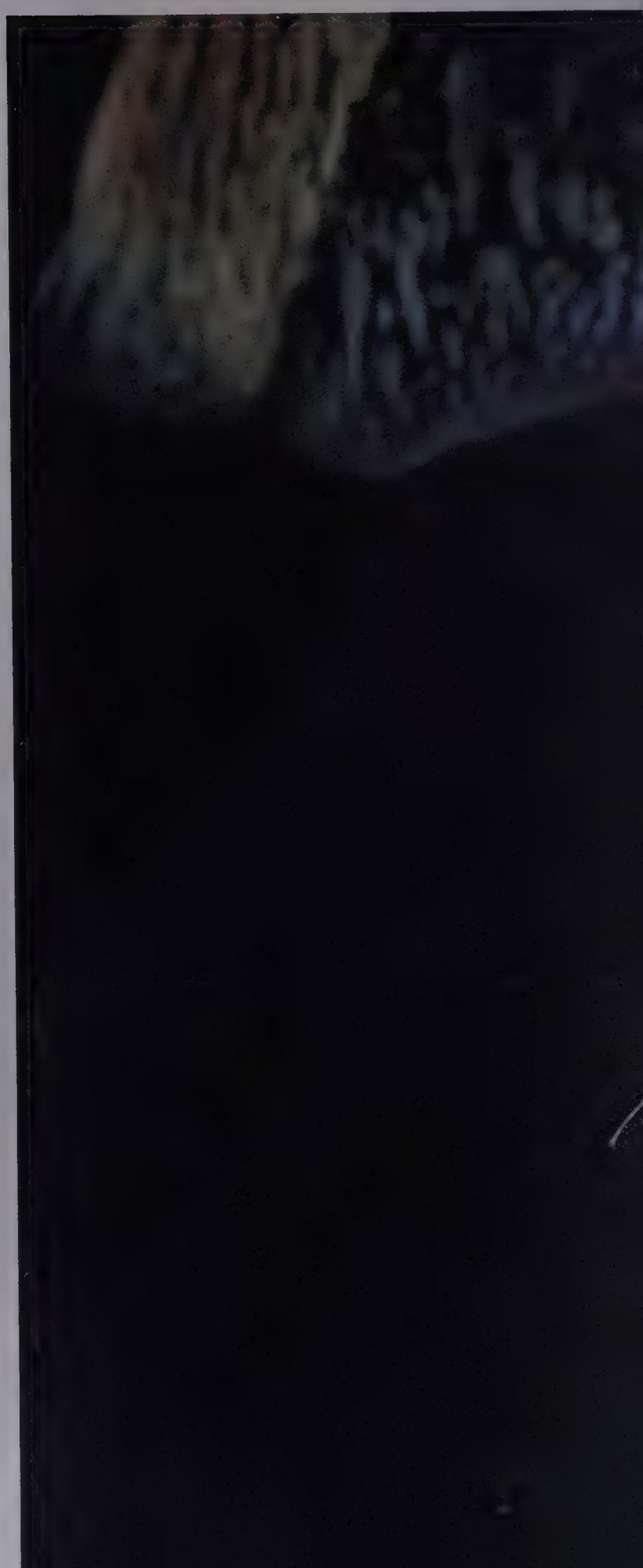
High Seas' Drifter

Photographs by Howard Hall



Pages 26 and 27: A purple jellyfish of a recently discovered species drifts with the currents off the northwest coast of Baja California (a shadowy companion can be seen in the background). A crab, below, is one of many "kleptoparasites" on the jellyfish's arms. Near right: A diver approaches the bell of the jellyfish. Center right: A medusa fish and tiny crabs are protected by the jellyfish's stinging tentacles. Far right: Near the reef, bright orange garibaldis and other reef fishes nibble at a jellyfish.

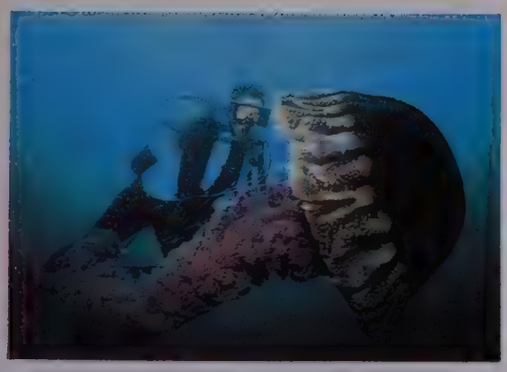


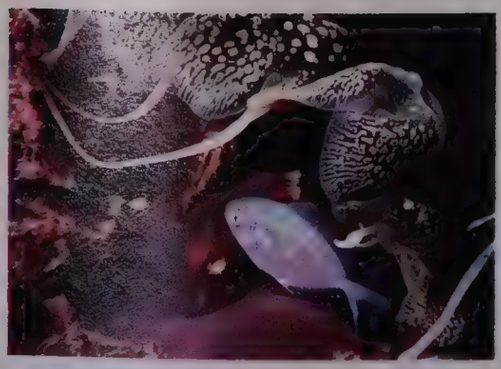
During several days of filming in the waters around Islas de Los Coronados, Baja California, Howard Hall and his crew were visited by hundreds of dark purple jellyfish of a previously unknown species; each measured almost twenty feet in length and had umbrellalike bells almost three feet in diameter. Rhythmic contractions of their bells propelled the giant medusae slowly through the water, but the strong current carried them toward a reef near shore. Swimming alongside a jellyfish, the divers could see a multitude of other animals living around and within the long, pleated oral arms dangling from the medusa's bell. As the jellyfish approached the reef, bright orange garibaldis and other reef fishes emerged from the sheltering rocks to nibble at the tentacles of this floating giant (the word *tentacle* refers only to the wispy appendages that hang from the outer edge of the umbrella). Kelp bass followed, waiting for tiny crabs and other organisms to fall from the jellyfish, which would probably be killed by the surf.

Much as a reef or a kelp forest provides shelter for larval fish, young turtles, and other vulnerable creatures of the open ocean, the purple jellyfish, too, harbors communities of its own. Small fishes and crustaceans, such as crabs and amphipods, hide among the folds of the jellyfish's oral arms. Covered with stinging cells called nematocysts, the oral arms stun small prey that brush up against them. A coating of mucus traps plankton encountered as the jellyfish drifts through the water. In jellyfish of this size, the oral arms may have a surface area of almost a hundred square feet, and the food they gather is passed upward to the mouth of the animal.

Scientists do not know why, but the jellyfish's passengers are immune from this fate. These "kleptoparasites," picked up by the jellyfish during its travels, live by stealing bits of their host's food. Most kleptoparasites attach to the host as larvae, but judging from the size of some of the crabs on these giant medusae, free rides may last several years.

In size, the purple apparitions rivaled other large species found on the West Coast and elsewhere. What made them extraordinary was their apparent rarity: the species, tentatively called *Chrysaora* sp., had never been described by scientists. According to Ron Larson, a marine biologist at the U.S. Fish and Wildlife Service in Brunswick, Georgia, who is classifying the dark purple medusae, "It is extremely rare to find a new species of this size that has gone unnoticed, especially in an area like California where the marine life is so well known. But ocean currents occasionally shift and bring new species to light." Dark purple jellyfish started to appear on the beaches of Baja California in July 1989, and as the summer progressed, their corpses were found washed ashore as far north as Santa Monica. Larson believes that a current from the south probably carried them in from the open ocean or from waters off the Mexican coast, areas that remain relatively unexplored.—*R. A.*





After finishing their afternoon chores, Shipibo women in Paococha gather with their children for a visit. A Shipibo woman has an average of ten children during her lifetime.

Family Planning, Amazon Style

Amid cultural change, high fertility imposes new hardships on an Indian people

Text and photographs by Warren M. Hern

"When you come back, don't forget to bring *toötimarau,*" Chomoshico called to me. I was leaving the Shipibo Indian village of Manco Capac, on the banks of the Pisqui River in the Peruvian Amazon, where I had been doing medical research. Chomoshico was nearing the end of her eleventh pregnancy. She already had seven living children. Neither she nor her husband wants more. "Enough. Clothes cost," they told me. "I'm tired of having children," she said. "I almost died with the last one." Her husband has tuberculosis.

Toötimarau means "medicine to keep from being pregnant"—birth control. I knew I could promise Chomoshico worm medicine for her children's parasites, and I might be able to bring her vitamins and iron for her pregnancy, even medicine for tuberculosis. But while I could informally provide other kinds of medical care, I could not arrange to bring her birth control without risking reprisals from politicians who are against it. The Shipibo have been asking me for *toötimarau* for more than twenty-five years, but I haven't been able to arrange any yet. I can only refer them to a Peruvian doctor in Pucallpa, many days away by canoe. Most can never get there. The men even pull me aside to ask if I know about an operation to "fix" men—vasectomy—and, again, I tell them the name of my medical colleague in Pucallpa.

In the same village, a few weeks before, a young girl had died on her thirteenth birthday trying to give birth to twins. And in that girl's natal village, just up the river, I had just seen my first case of frank starvation among the Shipibo Indians, with whom I had worked as a physician and scientist since 1964. The starving man had tuberculosis. His family, which would normally have taken care of someone so ill, was away working for a logging company.

Chomoshico's desperate request for birth control, the death of the thirteen-year-old girl, and the plight of the starving man are all related. The Shipibo's own high fertility, uncontrolled by any effective means, is compounding the problem of the population pressure created by an influx of outsiders, who are moving into Shipibo territory and destroying the natural resources.

The Shipibo Indians who live along the Ucayali River and its tributaries, such as the Pisqui, notice that the fish are getting smaller and harder to find, and that the game animals they rely on during the rainy season—when fish are almost impossible to catch—are more elusive than in the past. Palm leaves for thatching roofs seem scarcer, and people have to trek long distances, sometimes a mile or more, to gather firewood, once available a few steps away. People are aware that their own village is growing, that they do not know all its inhabitants, that the village school is crowded. Sometimes they have to go all day without eating fish. The Shipibo word for fish, *piti,* is also their word for food: a Shipibo without fish is truly poor.

In this crisis, the Shipibo are not alone. The Peruvian government has urged desperate people from the crowded coastal cities and Andean communities to settle and live in the jungle "paradise." They have. Pucallpa, the major port on the Ucayali, the "highway" river that becomes the Amazon, was probably an aboriginal Shipibo settlement (its Shipibo name means "red earth"). In the 1940s, just before the trans-Andes highway was put through to Pucallpa from Lima, the settlement's population was about 2,500. When I first visited Pucallpa in 1964, the population had grown to about 25,000. It was a raw, dusty, frontier town with dirt streets and Saturday night gunfights. More than 250,000 people live there now—a hundredfold increase in fifty years.

With the local waters already depleted, fishing boats from Pucallpa speed downstream more than 150 miles, where they take all fish more than two inches long with drift nets, pack the fish in ice, and start back up the river. The smaller fish are discarded to rot. There is not much left for the Shipibo, for the mestizo colonists from elsewhere in Peru, for the large fish, for the alligators, or for the wading birds that used to line the shores of the Ucayali. Areas around Pucallpa that were covered

A Shipibo man skins a fifty-six-pound armored catfish, below, one of many catfish species found in the Ucayali. In recent years, however, such catches are exceptional. The human population along the river has been growing explosively, and the Shipibo report that fish—their traditional staple food—are smaller and harder to find. Right: Shipibo women from the village of Paohyän harvest rice cultivated on a dry lake bottom.

by canopy rain forest in 1964 now look like Oklahoma. The hundreds of bird species that enlivened the forest have been replaced by emaciated cows. Swamps filled with fish are replaced by causeways carrying buses and motorcycles. Twenty years ago, a traveler camped on the beach of the Ucayali River could not sleep for the sounds of fish splashing and alligators hunting them. There aren't enough fish to keep one awake now; the traveler is kept awake by the whine of fishermen's outboard motors.

Instead of living by subsistence fishing and horticulture, as the Shipibo principally do, their new neighbors exploit the environment to make money. First come the timber cutters, followed by cattle ranchers, commercial fishermen, and the farmers of bananas, rice, and other cash crops. The resultant deforestation and flooding have eliminated some crops and game animals that were sources of food for the Shipibo in the rainy season. The Shipibo themselves are drawn into the money economy and sometimes sell products from scarce animals (such as water turtle eggs) in order to get cash.

The Shipibo painfully admit that, although they work much harder than before, they don't have enough money for clothes (which they used to make by hand from woven cloth) and schoolbooks for their children (not a factor thirty years ago). They now have to buy food at times, even though it was previously plentiful.

The Shipibo (and the closely related Conibo) are the dominant indigenous people of the upper Peruvian Amazon. They have survived there for about a thousand years, but only by battling fiercely with other tribes and exhibiting a pragmatic tenacity in the face of colonization. Before the European conquest, they may have numbered more than 50,000. By the early twentieth century, fewer than 3,000 remained. Somehow they escaped the further decimation or complete extinction that befell many other Amazon tribes exposed to European diseases, enslavement, intertribal warfare sponsored by rubber tappers, and other openly genocidal attempts to rid the Amazon of its native inhabitants. Their population is now about 30,000 and growing.

The last smallpox epidemic was in 1964. But now, in addition to the modern plagues of tuberculosis and cholera, the Shipibo have a new health problem: high fertility, which places pressure on resources and takes a heavy toll among Shipibo women.

In the past the Shipibo controlled their birth rate and population growth in a variety of ways: by sexual abstinence, by abortion (using pressure on the uterus), by in

fanticide, and by the use of herbal contraceptives. Knowledge of these contraceptives was passed down through the generations from mother to daughter, from grandmother to granddaughter. But several things happened to interrupt this tradition. The horrifying epidemics that wiped out whole villages following European contact prompted shamans in related tribes to forbid the practices of infanticide and abortion. The Shipibo shamans may also have taken this step, but more likely, Christian missionaries played a role in disrupting the cultural traditions that controlled fertility. In 1697, the Shipibo massacred a group of Franciscans who were insisting that the Shipibo give up polygyny (multiple wives). Today, the custom remains strong in some parts of the Shipibo culture area but is declining in villages close to centers of Western influence.

Even though polygyny allows some men to have more offspring than others, it permits women to have fewer children with longer intervals between births. This arrangement has several important effects: it allows women to recover from each pregnancy; it allows children to gain maturity before being weaned and placed on a diet of all solid foods; and it reduces the total number of children borne by individual women. The result for the group is that women have a better chance of recovering from pregnancy and therefore of living longer, and child survival is better.

These advantages of polygyny are often cited by members of traditional societies, whose strategy is, not to have as many children as possible, but to have as many as possible that survive to adulthood. A final result of polygyny, paradoxically, is that community fertility could be restrained.

My acquaintance with Shipibo methods of controlling fertility began in 1964, when I was a third-year medical student from the University of Colorado. I had just finished working intensively for several months at the Hospital Amazonico "Albert Schweitzer" near Pucallpa, and had traveled to the Shipibo village of Paococha to learn about native ideas concerning the nature, treatment, and control of disease. A Shipibo friend who was helping me, Ambrosio, came to me one day to tell me that his wife was bleeding to death: she had just had a baby. Ambrosio asked me to see her, and I treated his wife for retained membranes and postpartum uterine atony (relaxation of the uterus). She recovered, and he asked me what he could do for me. I told him I would like to learn about medicines that women use to control pregnancy. His aunt Julia was the local expert.

From Julia I learned that Shipibo women have several such herbal prepara-

tions. One of the most common is called *toötimahuaste* (*toöti* means "pregnancy," *ma* means "not," and *huaste* means "herb"). Taken as a tea during three successive menstrual periods, it is supposed to cause sterility.

In 1969, for my master of public health thesis, I returned to the village to conduct a more formal census and collect the inhabitants' reproductive histories. I asked the Shipibo women in my survey if they knew about these medicines and if they used them. They roared with laughter at the idea of a male gringo asking these intimate questions in their language. Then they usually told me that they knew about them; many had used them. Some of the women had seriously harmed themselves by using highly toxic natural substances in a desperate attempt to control fertility.

At first I was puzzled to find that women who had used the herbal contraceptives had more children, on the average, than those who hadn't. This turned out to be because older women, who had already had many children, were more likely to have used the herbal contraceptives. But my doubts about the effectiveness of the traditional contraceptives were renewed when I analyzed the results of my two population studies in 1964 and 1969. The Shipibo in Paococha turned out to have the highest fertility ever recorded for a human group, with a woman having an average of ten births during her reproductive life.

Moreover, their rate of population growth was nearly 4.9 percent per year, with the population doubling every 14.5 years. Such a population explosion had to be fairly recent, for if such a rate had been in effect for very long the population would have been huge. The phenomenon could not be completely explained by better medical care (some of which I had provided) and a declining death rate. Either the herbal contraceptives didn't work, or I wasn't getting all the information.

There were two other factors. By 1969 a large extended family from down the Ucayali river, at the periphery of the Shipibo territory, moved into Paococha. Several of the men had multiple wives. (The local, "downtown" Shipibo assured me that, unlike themselves, the new family was composed of *salvajes*—savages—and that they practiced the old ways, including polygyny.) Because missionaries and schoolteachers discouraged it, this family structure was becoming rare.

The second factor was suggested to me when I remembered that the Shipibo always observed certain taboos, including

A Paohyän family, left, takes refuge in its pole-and-thatch house during an exceptionally high seasonal flood of the Ucayali River. Below: A Shipibo health worker administers intravenous solution to rehydrate a cholera victim in the Pisqui village of Nuevo Eden, in July 1991. The girl recovered, but that year's cholera epidemic killed about twenty Shipibo in the area.

"dieting," when taking medications of any kind. I asked the women what they did when they took *toötimahuaste*. They replied that one cannot eat salt, honey from the forest or other sweets, ripe bananas, and certain kinds of fish. And a woman taking *toötimahuaste* may not have sex. This would mean an abstinence of three months or more. Right away, I suspected what epidemiologists call a "secondary noncausal association" between the use of herbal contraceptives and fewer pregnancies.

Postpartum sexual abstinence is often linked with polygyny in tribal societies. The woman who has just given birth may not sleep with her husband for a period of time, which may be from three months to three years. During that time her husband sleeps with one of the other wives. In Shipibo tradition, it is not uncommon for a man to have two or three wives. Because women in polygynous marriages might be better able to observe the sexual abstinence associated with herbal contraceptives, and because this might help these women have longer birth intervals, I speculated that a decline in the practice of polygyny could be contributing to the community's high fertility.

To be sure of this, I had to determine that, on average, the birth intervals were indeed longer for women in polygynous marriages than for women in monogamous mariages and that fertility was actually lower for the former than for the latter. Further, I wanted to determine if the rates of polygyny differed among the villages, and if so, whether less polygyny is associated with lower or higher community fertility. By studying Shipibo villages that were separated by long distances and had different levels of cultural contact with Western society, I could compare the relationship between polygyny and fertility.

Up on the Pisqui River, Shipibo lives are more traditional than in the Shipibo villages lining the Ucayali. The Pisqui is much smaller and fluctuates more quickly than the Ucayali. It contains fewer fish and other edible wildlife. The Pisqui Shipibo live more by hunting and gathering than their Ucayali brethren. They are more isolated from outside influences, and have been since at least early colonial times.

In 1983 and 1984, I studied eight Shipibo villages in different states of cultural transition. Six of the villages were as much as sixty miles up the Pisqui. The results of the study showed that polygyny is generally more common on the Pisqui, and that longer birth intervals occur in the polygynous unions there. In some Pisqui villages, 45 percent of the women were in polygynous marriages, whereas in Paoyhän, a new Shipibo village on the Ucayali, only about 5 percent of the women were in this kind of union.

Comparing the birth interval lengths and fertility of all women, regardless of their villages, I found that, on average, the birth intervals for women in polygynous marriages were thirty-four months—four months longer than those of women in monogamous marriages. And most significant, women in monogamous marriages had 1.3 more children during their reproductive lives than women in polygynous marriages. Accordingly, in villages where polygyny was more common, the average intervals between births were longer and community fertility rates were lower.

The most acute health problem for the Shipibo, as both they and I see it, is epidemic disease—tuberculosis, cholera, and

influenza, to mention a few. These diseases carry off the older people who know the cultural traditions, and they carry off many children. But the long-term problem is high fertility, which is placing pressure on the diminishing resources. Weakened by increasingly poor nutrition, the Shipibo are more vulnerable to epidemics. In their case, population growth means poverty and disease.

For Shipibo women, high fertility means sickness and death. They have an extremely high rate of cervical cancer, which is probably related, among other things, to early childbearing and many pregnancies. I estimate that the maternal mortality ratio—the proportion of women who die from pregnancy and childbirth—is roughly one for every hundred live births, one hundred times higher than in the United States.

A larger question raised by studies such as mine is whether we really understand how fast the world's population is growing and will grow in the future. The Shipibo are essentially not counted in the Peruvian census, and neither are their mestizo and other Shipibo neighbors. Numbers sent to the government offices are highly inaccurate (but then I, for one, never received a U.S. census form in 1990).

From my experiences in Latin America, I would speculate that official census counts are missing at least one in ten people and perhaps every fourth person. Some of those groups excluded appear to have population growth rates of more than 3.5 percent. If this is true—and if it is similarly true in other parts of the developing world—world population growth rates may not only be higher than official estimates but may also grow higher as traditional societies like the Shipibo experience rapid cultural change.

Human population growth is not new. But there was a time, long past, when it took 100,000 years for world population to double. Soon after agriculture was invented, the doubling time dropped to 700 years. Now our population is doubling every 35 to 40 years. What happened?

While there are many answers, one emerges from this study and others like it: many human societies that controlled their fertility in the past have lost the tradition of doing so in the frenzy of modern cultural change. The old methods that reduced births have not yet been replaced by the new technologies of fertility control. The result is chaos, suffering, more cultural change, and in some cases, even more rapid population growth. Where will it stop?

For the Shipibo it stops when the beloved *yoshanshico* (grandmother) dies of tuberculosis and takes with her the ancient Amazon traditions of pottery making and weaving and knowledge of the plants and seasons. It stops with the loss of half the village's children to a measles epidemic. It stops with the death of a beautiful thirteen-year-old girl in childbirth. It stops when the village chief, a vigorous and intelligent young man, dies of cholera. It stops when the legendary hunter of *piache,* a giant fish once commonly found in Amazon lakes, returns after three days in the bush with his canoe empty and his harpoon unused. His family gets by on another meal of banana porridge.

It stops when the bright but superfluous young men and women of the village leave for the city, where they can get low-level jobs and survive. Their village education, which kept them from the forest and from learning their environment and own culture, has given them only minimal skills for life in town, where they sometimes conceal their cultural identity to get jobs.

It stopped for Ambrosio's wife when she died, exhausted, trying to give birth the next time, at the end of her twelfth pregnancy. The previous child proved to be mentally retarded, probably the result of a two-day labor and difficult delivery. For Ambrosio, a friendly man with a mischievous smile and quick wit, it stopped when he died from tetanus two years later. For Julia, who became one of my dearest friends in life, a woman who had outlived two husbands and thrown out several others, who was fiercely independent and could hunt and fish with the men, who was a skilled artist and walking library of Shipibo culture, it stopped when she started coughing blood and bled to death in a few minutes in front of her horrified family. The Shipibo are being forced to choose between buying tuberculosis medicine for people like Julia and building schools for their children.

Below and right: Mothers with their children. The influence of outside cultures on traditional life styles has driven Shipibo fertility higher, but at a great cost to maternal health and survival.

For me, there are few things as delightful as the sound of Shipibo children laughing. The Shipibo love their children, and it shows. But what is ahead for people like Chomoshico and her husband and children? The inexorable arithmetic of population growth is upon them, and the consequences for their environment and families are plain to see. As a public health physician, I cannot help noticing that the Shipibo's fertility problems are inseparable from their other health problems and the changes going on around them. I also cannot help noticing that each family, with few exceptions, wants to limit its fertility but has no safe, effective means of doing so. That is not a scientific issue, but a political problem that neither I nor the Shipibo can solve. □

A red crossbill, left, husks a ponderosa pine seed. Below right: The seeds of most black spruce cones are sealed between dense scales.
William Ervin

A Crossbill's Twist of Fate

An effort to help pine martens may have doomed a remarkable Newfoundland bird

by Craig W. Benkman

In the avian world, bill design is a prime example of evolutionary fine-tuning. Shorebirds such as oystercatchers are able to prise open their sealed quarry, hummingbirds have stilettolike bills to probe the deepest nectar-bearing flowers, and kiwis smell out earthworms thanks to nostrils located at the tip of their beaks. But few birds are more intimately tied to their source of sustenance than are crossbills. Two species of these finches, named for the way the upper and lower mandibles of their bills crisscross, rather than meet in the middle, reside in the evergreen forests of North America and feed on the seeds held within the cones of pine, spruce, tamarack, and other coniferous trees. Their bills are as finely adapted to a cone as a key is to a lock. But recently, in the course of my investigations of crossbill feeding mechanics, I found what can happen when, relatively suddenly, the key no longer belongs solely to the crossbill.

According to folklore, malocclusion in crossbills resulted when the birds tried to pull the nails from the cross of the crucified Christ. The true efficiency of the bill is evident when a crossbill locates a cone. A crossbill may either feed on the seeds when a cone is still on the branch, or it may pluck the cone off. If the bird opts to remove a cone from a tree, it takes the cone to a stable perch, and grasps it in one foot. (Crossbills are "handed," that is, they use the right foot if the lower mandible goes to the left and vice versa.) Using a lateral motion of its lower mandible, the bird separates two overlapping scales on the cone and exposes the seed. The crossed mandibles enable the bird to exert a powerful biting force at the bill tips, which is critical for maneuvering them between the scales and spreading the scales apart by lateral abduction. Next, the crossbill snakes its long tongue into the gap and draws out the seed. Using the combined action of the bill and tongue, the bird cracks open and discards the woody seed covering and swallows the nutritious inner kernel. This whole process takes but a few seconds and is repeated hundreds of times a day.

Red crossbills are fairly widespread in North America. In the eastern parts of the continent, they are partial to forests containing red and white pines. The more northerly white-winged crossbills are denizens of boreal forests in Canada and Alaska. In early summer, white-wings seek out developing cone crops of white spruce and tamarack trees. Because the production of these cone crops fluctuates tremendously from year to year and often fails completely over large areas, the annual searches are often extensive; in their quest, the birds may cross the continent from Alaska to Newfoundland.

The bills of different crossbill species and subspecies vary—some are stout and deep, others more slender and shallow. (Recent research has suggested that various crossbill subspecies may well be full species in their own right, a view that my ecological work supports, but which has not yet been confirmed.) I had been studying crossbills in the laboratory and the field since 1982, and I found that as a rule, large-billed crossbills are better at securing seeds from large cones, while small-billed crossbills are more deft at removing the seeds from small, thin-scaled cones. Moreover, the degree to which the cones are naturally slightly open or tightly closed helps determine which bill design is the right "key" to the cone.

One anomaly apparent from my studies was the subspecies of red crossbill known as the Newfoundland crossbill, a bird I

Alan Wilkinson; Valan Photos

was familiar with only from written accounts. Endemic to that island, this bird failed to exhibit the crossbill's penchant for wandering and did not fit into the pattern of bill sizes and cone types that held true for the other crossbills I had studied. The Newfoundland crossbill has a large, robust bill, yet most of Newfoundland's conifers have small cones, the same kind of cones that the slender-billed white-wings rely upon. What was the large bill of the Newfoundland crossbill adapted for?

Moreover, why was the Newfoundland crossbill confined to the island, while white-wings regularly cross the narrow strait that separates Newfoundland from Labrador? Why could Newfoundland forests support both the nomadic white-wing and the more sedentary Newfoundland crossbill, whereas mainland forests could not support the Newfoundland crossbill?

From aviary and field studies, I knew

that the white-wing's bill is ideal for extracting seeds from slightly open black spruce cones; its very slender mandibles slide between the relatively stiff scales with a minimum of resistance. Yet black spruce was the one tree that I could envision the Newfoundland crossbill relying upon. Unlike white spruce and tamarack, black spruce is a fairly regular cone producer and holds its seeds throughout the year, so that on an island the size of Newfoundland, a crossbill could find black spruce seeds year round, year after year. The Newfoundland crossbill, however, could not compete with the white-wing for seeds in slightly open black spruce cones; it might instead rely upon seeds in closed black spruce cones. I also knew from my research that seeds in closed black spruce cones could be harvested by the mainland red crossbill, whose bill size falls between that of the white-wing and the Newfoundland crossbill. My data also indicated that as bill size increases, seeds in hard-closed cones, like those of black spruce, become progressively more accessible. The large bill of the Newfoundland crossbill started to make sense. In autumn, after black spruce seeds mature, about one third of the cones open. These are the cones that sustain white-wings when other food is scarce. The rest of the cones remain closed, their seeds inaccessible to delicate bills. Seeds in closed black spruce cones might then be the resource for which the heavy bill of the Newfoundland crossbill is adapted.

Nevertheless, a major problem remained. Even though the Newfoundland crossbill's large bill would reduce the time required to remove seeds from closed cones, the bird would still be unable to remove seeds fast enough to survive a winter day. I estimate that the small white-wing needs to consume a spruce seed about every seven seconds throughout an average winter day to survive. While a white-wing can forage this fast on slightly open cones, no crossbill could do so on closed cones as tough as those of mainland black spruce.

I could imagine Newfoundland crossbills managing to survive only if the cones on Newfoundland differed from those on the mainland. After some thought, this seemed not only possible, but likely. Over time, conifers evolve defenses in response to predators. For example, in the presence of voracious seed eaters such as squirrels, conifers alter their cone structure, sometimes evolving thicker scales. When the glaciers retreated from Canada about 10,000 years ago, red squirrels colonized

John Hyde; Bruce Coleman, Inc.

Red squirrels are partial to white spruce. Seeds can be savored on the spot, below, or whole cones can be jettisoned from the tree, left, and cached for later use.
Kennan Ward; Bruce Coleman, Inc.

the mainland, but not the island of Newfoundland. In the absence of squirrels, I reasoned, black spruce may have put more energy into seed production, while proportionately reducing seed defenses such as cone scales. If Newfoundland cone scales were thinner and easier to open than those on the mainland, both the Newfoundland crossbill's large bill and its absence from the mainland could be explained.

I now needed information on cone-scale thickness. I contacted Blake Maybank, a naturalist at Gros Morne National Park in Newfoundland, who agreed to gather and send cones to me. Even before I began to measure them in my office in Princeton, New Jersey, I knew these cones had thin scales; they crumbled relatively easily in my hand. Even my nonconifer-wise colleagues appreciated the differences between these and the mainland cones I had gathered, differences I confirmed by scale measurements. Compared with mainland cones, Newfoundland cones had scales about 15 percent thinner.

Over about 10,000 years and many fewer spruce generations, and in the absence of red squirrels, Newfoundland's black spruce had evolved thin cone scales. On the squirrel-settled mainland, black spruce had cone scales too thick to allow Newfoundland crossbills to feed on them, but on the island, the birds could take advantage of a bounty of soft cones.

Unfortunately, the story does not end here; Newfoundland is no longer free of red squirrels. To provide food for the pine marten, a fur bearer that had been overtrapped for its pelt, squirrels were introduced into Newfoundland in the early 1960s. The scheme was to provide additional prey for the pine marten to bring its population back up to trappable numbers, although this has not happened. But as seed competitors and evolutionary agents on black spruce, the squirrels may have a devastating effect on the Newfoundland crossbill.

Red squirrels have flourished in the abundant, reliable, soft-coned black spruce forests of Newfoundland. Census data indicate that the squirrel population is now about twice as dense on Newfoundland as in mainland spruce forests, and my hunch is that a tenfold difference in density is closer to reality. Red squirrels are not common in black spruce habitats on the mainland, apparently because of black spruce's tough cones. One study conducted in Alaska showed that red squirrels could not survive when given only black spruce cones, but did quite well when provided with only white spruce cones.

Squirrels on the island are more abundant than on the mainland, and they remove and cache more cones than do mainland squirrels after the cones mature in autumn. In general, squirrels store many more cones than they need—in the ground or other hiding places—making much of the cone crop inaccessible to crossbills, particularly in winter. For example, under similar conditions, mainland squirrels remove less than 20 percent of the black spruce cones, while on Newfoundland, they remove more than 90 percent. This statistic, determined by Rick West, a biologist with the Canadian Ministry of Wildlife, was met with skepticism by those unaware of the differences between Newfoundland and mainland cones.

The bottom line is that, because of the introduction of red squirrels, the Newfoundland crossbill's days are numbered. Either the squirrels will simply outcompete the birds, or the black spruce will evolve thicker scales, sealing the birds' food supply in an impenetrable cone.

My first hint that the once common Newfoundland crossbill was indeed declining was from correspondence with Hank Deichmann, a naturalist long familiar with the birds of the island. Annual Audubon Christmas Bird Counts provided additional information on crossbill numbers. Of several counts available, I chose to analyze one from Terra Nova National Park, because it contains a large, undisturbed spruce forest and because it covers an area that a bird-finding guide recommends as one of the best places to see the Newfoundland crossbill. An analysis revealed that by the early 1970s, ten years after the introduction of squirrels, New-

Dale Wilson; First Light

A female white-winged crossbill in Alaska uses its bill to spread apart the scales of a Sitka spruce cone, below, and will use its tongue to extract the seed. The forests of Newfoundland, right, contain black spruce trees with relatively thin-scaled cones, making the seeds accessible to the island's native crossbill.

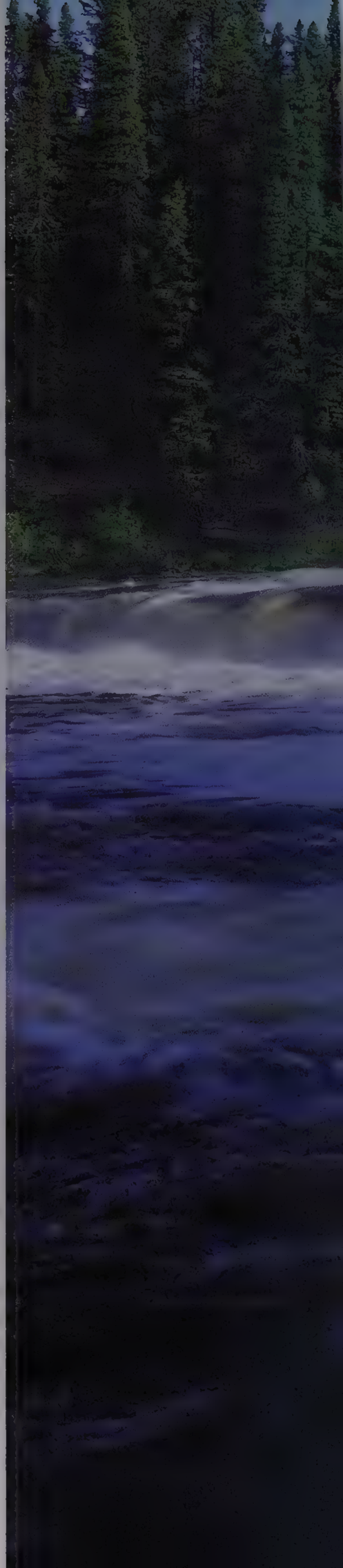
Chlaus Lotscher

foundland crossbill densities had plummeted, and that the birds are rare to absent today. Although red crossbills are still reported from Newfoundland, most of these are probably other, mainland subspecies of red crossbill, which apparently move on and off the island like white-wings. We may not have to wait for the black spruce to evolve thicker cones scales for the Newfoundland crossbill to go extinct.

One hope for the Newfoundland crossbill exists on the islets off the coast of the main island, some of which have black spruce forests that remain uncolonized by red squirrels. At least one pair of Newfoundland crossbills have been seen on an islet, but whether the islets are large enough to support a viable crossbill population is unknown. Anticosti Island in the Gulf of Saint Lawrence is the one other potential refuge for Newfoundland crossbills. The birds were found there in the 1950s, the island has ample black spruce, and squirrels are absent.

We are now on the verge of losing a singular subspecies of crossbill, all because of a misguided introduction of a competitor. Furthermore, the outlook for several other subspecies of crossbill, each with a bill designed for foraging on a particular conifer species, may not be much better. One crossbill I have begun to study seems to be adapted to feeding on Sitka spruce along the coastal belt of the Pacific Northwest. This conifer has been decimated by the timber industry, and if efforts are not made to protect the ancient forest in which it grows, its associated crossbill may go the way of the Newfoundland crossbill.

As I write, I am nestled under a palm tree on a beach in the Dominican Republic. While the beach is not typical crossbill habitat, the nearby mountains of Hispaniola are home to an endemic white-winged crossbill population. These birds differ dramatically from the white-wings in the boreal forests of the north, but are similar to most other island populations in that they occupy an island lacking squirrels. Although this crossbill is uncommon, its fate is at present more secure than that of the Newfoundland crossbill. Dominicans have begun to preserve their pine forests and to reforest, practices that could make the Hispaniolan crossbill's future brighter than that of several crossbill subspecies in the forests of the island's much wealthier neighbors to the north. □



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Questioning the Caterpillar

How a curious young girl became one of the premier painters of nature's wonderland

by Sharon D. Valiant

In the icy winter of 1717, Peter the Great's staff traveled across Europe to the czar's new city of Saint Petersburg. With them they carried nearly 300 watercolors by Maria Sibylla Merian, for upon seeing her work in Amsterdam, the czar had decided to found the first art museum in Russia. Negotiations for their purchase from Merian's family had been completed on the last day of the artist's life, and these magnificent watercolors—many of them of plants and animals from the jungles of South America—were being moved to one of the world's coldest cities. The czar continued to acquire Merian's work, and the Russian holdings eventually became the largest collection of her art in the world.

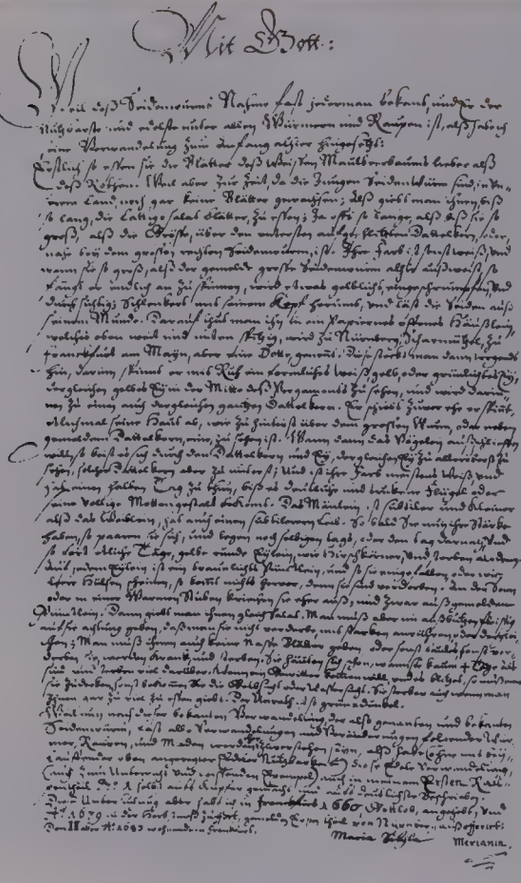
Merian was well known until the early nineteenth century. Among those who consulted or copied her work were the German poet Goethe, the Swedish botanist Carolus Linnaeus, and English naturalists Eleazar Albin (author of the first volume, in 1720, of English butterflies), Mark Catesby (author of a 1731 natural history of Carolina, Florida, and the Bahamas), and Moses Harris (author of the 1766 English classic on entomology). And Charles Wilson Peale, founder of the first American natural history museum, named a daughter Sibylla Miriam Peale.

European research in the last two decades has recovered important Merian material, particularly her journal, discovered in the archives of Saint Petersburg and published in 1976. The journal, containing roughly 133

A portrait of Maria Sibylla Merian appeared in an article by J. Cameron, in Naturalists' Library, *published in Edinburgh, 1841.*
Photograph by Craig Chesek, AMNH

The first plate in Metamorphosis Insectorum Surinamensium, *left, depicts the pineapple, which Merian described as "the most outstanding of all edible fruits"—and the cockroach, "the most infamous of all insects in America."*
Metamorphosis Insectorum Surinamensium; photograph by Craig Chesek, AMNH

Merian depicted the development of two species of Surinam's sphinx moths, right. The caterpillar above, wrote Merian, "ate voraciously." The one below contracted after being touched, "and foam ran from its mouth."
Metamorphosis Insectorum Surinamensium; photograph by Craig Chesek, AMNH



Merian made her first journal entry when she was thirteen and reported her surprise at seeing caterpillars spin cocoons and transform themselves into moths. The entry was accompanied by the watercolor of a silkworm's metamorphosis.
Academy of Sciences of the Russian Federation, Saint Petersburg; photograph by Peter Goldberg

pages of text with watercolors inserted on vellum scraps, was begun in 1660 when she was thirteen and continued through 1713, richly documenting the artist's exploration of the natural world.

Born in Frankfurt on April 2, 1647, Maria Sibylla Merian was the daughter of Matthäus Merian, a noted engraver, and his second wife, Johanna Heim. His first wife was the granddaughter of engraver Theodore de Bry, publisher of many famous books, including John White's drawings of the New World and a 1599 edition of Sir Walter Raleigh's voyage to Dutch Guiana (Surinam) in search of El Dorado. Matthäus Merian eventually inherited the family's business.

Matthäus died when his daughter was three, and a year later, her mother married the painter Jacob Marrel, who studied with the Dutch flower painters and the German still-life artist Georg Flegel, whose work followed the style of the German Renaissance master Albrecht Dürer. Recognizing Maria Sibylla's extraordinary talent, her stepfather began training her.

The discovery of the watercolors in her journal proved that Merian's artistic style was fully formed by the age of thirteen and remained unchanged throughout her life. Earlier biographers associated her with the Dutch flower school, but more recent analysis has aligned Merian almost completely with the German Renaissance—the direct link between Dürer and natural history art of the eighteenth and nineteenth centuries. Flegel and his student Marrel were the key influences upon Merian.

In 1660, the year she began her journal, the young Maria was raising silkworms. As she explained in the foreword to one of her books: "I was ever at pains to embellish my floral designs with caterpillars.... Through the example of silkworms, I came upon the metamorphosis of the caterpillars." In a later book, she added, "From my youth onwards...[I collected]...all the caterpillars I could find in order to study their

A process called wet-block engraving was used in the 1705 edition of Metamorphosis. *The first impression, right, was taken from the copper plate while the ink was still wet. The paper was then covered by a second sheet, producing a reversed image (inset), with finer, lighter lines than the original's.*
Metamorphosis Insectorum Surinamensium; photograph by Craig Chesek, AMNH

metamorphosis. I therefore withdrew from society and devoted myself to these investigations."

Understanding animals became the focus of her life, and from 1660 on she collected insects, recording and meticulously painting everything she could observe about their life cycles and behavior. Eventually her interests extended to beetles, frogs, lizards, and snakes—animals of a size she could capture herself—and her long-term observation of animals had no precedent.

Until 1668, when the Italian physician Francesco Redi published his theory that insects hatched from eggs, Aristotle's theory of spontaneous generation—that insects developed from putrid matter—had prevailed. In 1669, the Italian physiologist Marcello Malpighi published his treatise on the metamorphosis of silkworms. According to Merian's journal, however, she knew about the various stages of insect metamorphosis—from egg to caterpillar to cocoon to butterfly or moth—nearly a decade earlier.

In this period—the late seventeenth century—much was known about botany. Herbal, medicinal, and food plants from newly discovered areas of the world were pouring into Europe. But little was known about animals beyond the sixteenth-century work of Konrad Gesner, whose book featured unicorns and a whale with the god Neptune carved on its side. Knowledge of beasts was known mainly from medieval bestiaries, and as late as 1724, a mermaid was depicted in a book on animals. The same merchants and sailors who brought the new plants to Europe also collected beetles, lizards, butterflies, shells, and other marvels from far-off lands to fill the curiosity cabinets of the citizenry. Because

nothing was known about these mounted specimens, however, they were regarded simply as rarities. Against this backdrop, Merian pursued her investigation of animals.

At eighteen, Merian married Johann Andreas Graff, a student of her stepfather's. A daughter, Johanna, was born three years later, and a second daughter, Dorothea Maria, ten years after the first. By 1670, the family had moved to Graff's hometown in Nuremberg. We know from her journal that Merian continued to hunt insects. An entry in 1677 found her fishing a caterpillar out of the moat at Augsburg, and in 1681 she recorded a visit to the famous maze near Kraftshof searching for caterpillars. But Graff's career did not develop as expected, and Merian became the family breadwinner by teaching painting and embroidery and publishing three books of flower engravings in 1675, 1677, and 1680 that provided models for painting and embroidery patterns.

In 1679, Merian published her first book on European caterpillars, in which, according to the title,

> the wondrous metamorphosis and peculiar plant-nourishment of caterpillars, wherein by means of an entirely new inquiry, the origin, food and changes of caterpillars, worms, butterflies, moths, flies, and other similar little creatures together with their times, place, and special characteristics, for the service of naturalists, artists and lovers of gardens, are diligently investigated, shortly described, depicted from life, engraved on copper and personally published by Maria Sibylla Graffin, daughter of Matthäus Merian the Elder.

Published in German, the volume included fifty plates, depicting each caterpillar's development on the appropriate food plant. Merian's paintings of the metamorphosis of caterpillars—from eggs to butterflies or moths—confirmed Redi's theory of development from eggs.

Not only did Merian recognize nature as a continuous cycle; she also understood that the environment could

According to Merian, Tupinambis nigropunctatus, *the species of lizard depicted on the cassava plant, left, lived off dead animals and grew as big as a crocodile. "Unlike the crocodile," she wrote, "they do not attack human beings."*
Metamorphosis Insectorum Surinamensium; photograph by Craig Chesek, AMNH

change the timing of the metamorphosis. Upon observing one chrysalis that usually developed in April "emerging in December," she wrote, "I put this down to my having kept them in a warm room." She also included notes on a caterpillar's behavior: "It is their way, to roll together, when they are touched, and thus to remain like a ball." Another caterpillar "as soon as touched, turns its head quickly to and fro, as if in anger, and that it did about ten times one after the other." Her text indicated that she had also discovered the differences between butterflies and moths.

When her stepfather died in 1681, Merian returned to Frankfurt to be with her mother and eventually separated from her husband. A second book on caterpillars, again containing fifty plates, came out in 1683. In about 1685, Merian, together with her mother and daughters, moved to Castle Walta in Friesland to join the Labadists, a communal religious sect.

Founded by Jean de Labadie, a Jesuit-turned-Protestant, the group represented a radical fringe of the Dutch Reform Church. Members owned no property and, like Quakers, followed the "inner light." Labadists did not recognize marriage outside their group, so for Merian the move may have been a self-styled divorce; she probably returned to using her maiden name in this period. The sect had established a short-lived colony in Surinam, on the northern coast of South America, and curiosity cabinets at Castle Walta probably first introduced Merian to mounted tropical insects. At Castle Walta, she also continued her nature studies. In a journal entry in

Merian's study sheet of lizards, above, was found in the Saint Petersburg collection and was probably intended for a book on Surinam's reptiles and amphibians. It depicted, from top to bottom, Iguana iguana, Polychrus marmoratus, Ameiva ameiva, *and an unidentified species of gecko.*
Academy of Sciences of the Russian Federation, Saint Petersburg; photograph by Peter Goldberg

In addition to the frog and a crocuslike flower, Merian described giant waterbugs, "which the people there call Water-Scorpioenen. On 10 May 1701, I caught a few; on 12 May, flying creatures, like the one in flight above the plant, emerged out of them."
Metamorphosis Insectorum Surinamensium; photograph by Craig Chesek, AMNH

1686, she described the development of frogs' eggs and the metamorphosis of tadpoles in a dish of water.

After several days the black grains began to show signs of life and fed on the white slime that surrounded them. They even grew little tails so that they could swim in the water like fish. Halfway through May they grew eyes; eight days later two little feet emerged from the skin at the back and after a further eight days two little feet at the front, and they began to resemble small crocodiles. Thereafter the tail rotted away and they became proper frogs and jumped onto the land.

Sometime after the death of her mother in 1690, Merian left Castle Walta. From her journal we know that in late September 1691, she was in Amsterdam. In the thriving port city with trading connections throughout the world, Merian came into contact with Nicolas and Jonas Witsen, the mayor and secretary of the city, respectively; the anatomist and collector Frederick Ruysch; and the botanist Caspar Commelin; all of whom had extensive cabinet collections. How or when she made the decision to go to South America is unknown, but in June 1699, at the age of fifty-two, Merian set sail for the nearly three-month voyage to Surinam. Her traveling companion was her daughter Dorothea, and the purpose of her journey was to discover the origin of the insects she had seen in the Dutch curiosity cabinets.

For two years, Merian explored the rain forests of Surinam, collecting, observing, and painting caterpillars, beetles, lizards, and snakes. She received no help from local Europeans, and what aid there was came from Africans and native Indians who brought her specimens. Because of the harsh climate and illness (probably malaria), Merian returned earlier than planned, arriving in Amsterdam in September 1701, with enough material for at least two books—one on insects and a second on lizards.

While in Surinam, she painted watercolors of snakes, lizards, and beetles on large study sheets, but she continued to enter the caterpillars on vellum scraps in her journal. The compositions for the sixty plates of her *Metamorphosis Insectorum Surinamensium* were completed after returning to Holland. The book, which she published herself, appeared in Dutch and Latin editions in 1705. Caspar Commelin added plant identifications to the Latin edition and was probably responsible for the Latin translation. In 1719, a second edition appeared with twelve added plates but the last two were not her own. In all, five editions were published

In 1700, Merian visited a Surinam plantation where she found a giant owlet moth on a "liquid gum" bough. One of the world's largest moths, the owlet has a wingspan of up to twelve inches.
Metamorphosis Insectorum Surinamensium; photograph by Craig Chesek, AMNH

In Surinam, Merian painted watercolors in her journal, but the copper engravings for her book were done in Amsterdam. A study sheet, below right, shows a capricorn beetle, which also appears in her final composition, left, of three beetles on "a thorny plant."
Metamorphosis Insectorum Surinamensium; photograph by Craig Chesek, AMNH

from the original plates, the last in France in 1771. The plates disappeared about the time of the French Revolution.

In *Metamorphosis,* Merian introduced Europeans to the lush vegetation of the tropics. "The Indians lay the green leaves [from the Surinam cotton tree] on fresh wounds to cool and cure them." Watermelons

grow on the ground like cucumbers in Holland. They have a hard skin which gradually becomes less hard towards the inside of the fruit. The flesh is shiny and melts in the mouth like sugar; it is healthy and has a very pleasant taste; it is very refreshing to the sick.

Although she often included significant botanical information, Merian was mainly interested in these plants as food for the insects she was observing. Her emphasis on Surinam's animals predominated.

By the time Merian went to Surinam, she had been studying and observing animal life for forty years. Of a snake she wrote: "Its fat belly shows that it was carrying eggs"; of a wasp: "One can see that these nests are carefully built as a protection against both wind and rain to ensure the safety of the eggs." Animal behavior continued to intrigue her: "I took this nest into my house…to observe the behavior of the caterpillars; I found that they hid in the nest during the day and that they left in the evening to find food." One group of caterpillars "ate a lot and fast and their excrement was plenteous and large," while another group were "very slow and sluggish in their behavior."

Collecting was not always easy. "Since the tree is tall and hollow, it is not possible to climb up it and I therefore had it cut down to get hold of the caterpillars." Beetles "bit through the box and ran away." But her direct observations led

Academy of Sciences of the Russian Federation, Saint Petersburg; photograph by Peter Goldberg

Merian described the silkmoth caterpillars that fed on orange trees as "green with a yellow stripe over their whole body; on each segment there are four round orange-yellow beads covered with little hairs." The moths had a "pattern on each wing like a piece of Moscow glass."
Metamorphosis Insectorum Surinamensium; photograph by Craig Chesek, AMNH

her to challenge previously held notions, including one by the Dutch biologist and microscopist Antony van Leeuwenhoek. A caterpillar, she wrote, had

> fifty shining red warts. Leeuwenhoek is of the opinion that these are eyes. To date I have not been able to accept this opinion that they are eyes; in my view they would then be able to find their food from behind and from the sides, which I have not observed to be the case; they have no eye-sockets there.

In recently discovered correspondence between Merian and London apothecary and collector James Petiver, we find that he planned to translate *Metamorphosis* and the European caterpillar books into English. These editions failed to materialize. The same letters indicated that *Metamorphosis* was not successful in its first edition; it found an audience only with later reissues. The reptile volume never appeared, probably because Merian did not have the money to publish it. Her watercolors of reptiles and amphibians, however, are extensive but scattered throughout collections in Europe and North America.

How did she get the money to publish *Metamorphosis,* which at that time was one of the largest volumes ever printed? To cover costs, she took a commission to illustrate Georg Rumpf's *D'Amboinsche Rariteikamer*—(Amboinan Cabinet of Rarities)—the first natural history book from the Dutch East Indies. As an employee of the Dutch East India Company, Rumpf lived on the island of Amboina, halfway between the Philippines and Australia. The completed art for his book on shells, shellfish, and minerals was shipped to Holland piecemeal, but most never arrived. When Rumpf died, Merian was commissioned for new art, but the publisher, having little beyond a manuscript, tried to select matching specimens from Dutch cabinets. Thus many of the sixty plates in "the Amboina book," as Merian referred to it in her letters, depicted objects from the Indian and Atlantic oceans. Merian's name did not appear on Rumpf's volume and to confuse matters, duplicate watercolors existed that were signed by other artists. Not until the investigation and the publication in 1974 of Peter the Great's Merian collection did scholars find the original art.

In the last years of her life, Merian worked on a third European caterpillar book, which her daughter published in 1717. Merian also translated the first two volumes of the caterpillar books into Dutch and published them in 1713 and 1714, and she continued to work actively until she had a stroke in 1715.

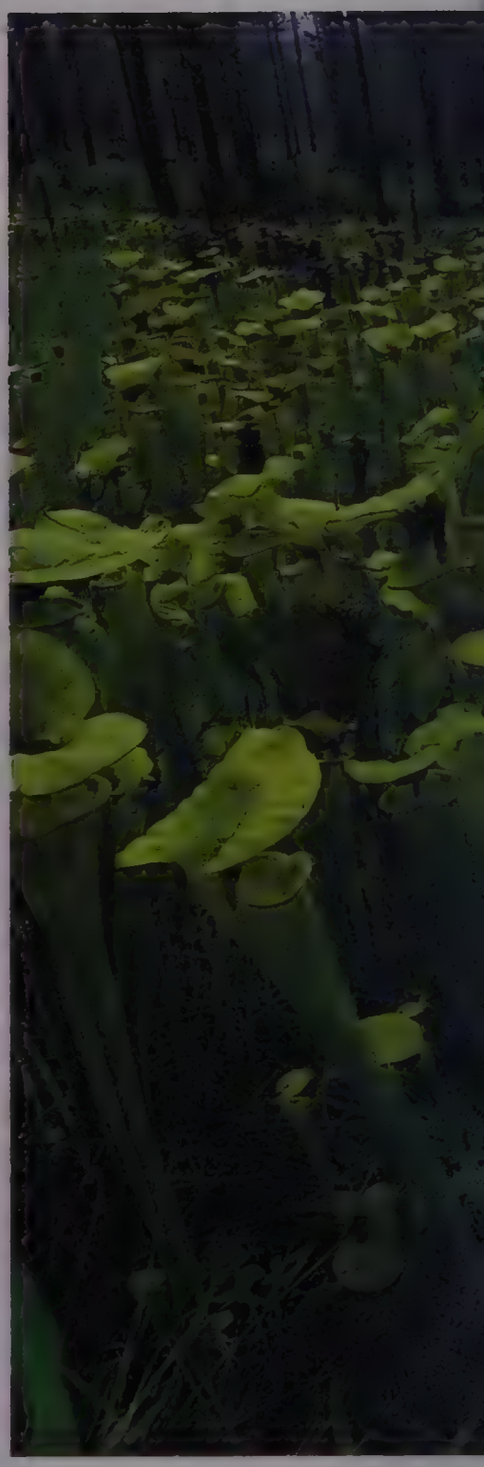
Not only did Peter the Great purchase a large Merian collection; he also convinced her daughter Dorothea to move to Saint Petersburg. There she and her husband, George Gsell, became close confidants of the czar and art teachers, continuing the Merian style and even training the painters who went with the Danish explorer Vitus Bering on his landmark expedition when he discovered the northern route to the Americas. George Gsell's instructions to artists on the expedition echo Merian's philosophy:

> To make it easier to portray everything true to nature one must have the subject before one's eyes and not paint from memory. To paint a fish, we must put it in water, so that it will not die; to paint grasses, we must dig them out with the earth, so that they do not wilt. We must paint birds and animals so as to reveal their physical peculiarities.

Until the nineteenth century, Merian remained an important figure in both science and art. Hans Sloane and Richard Mead, the two greatest collectors in eighteenth-century England, both had large collections of her art, as did the royal family of Denmark. When Mead died, his Merian collection was acquired by the English royal family. When the British Museum opened in 1759, works by Merian from Sloane's collections were on display. Linnaeus cited her work more than a hundred times. And in yet another tribute, German explorer Alexander von Humboldt had his portrait painted holding the flower of a plant species he named for Maria Sibylla Merian. □

Conecuh Bogs, Alabama

by Robert H. Mohlenbrock



The primary activity in Alabama's Conecuh National Forest is timber production. The original tree cover was harvested long ago, and subsequent generations of trees have been planted and cut. Stands of slash pine and long-leaf pine, arranged in densely crowded rows, cover much of the sandy uplands of the forest, interspersed with recently clear-cut tracts in which ragged tree stumps are surrounded by scrubby regrowth. But tucked away within this artificial and often unattractive landscape are more than two dozen pitcher plant bogs, ranging in size from a few square feet to a few acres, that still support a remarkable variety of plants and animals.

Pitcher plants can be found in boggy habitats all across the Coastal Plain of the southeastern United States, from the Carolinas and Florida to southern Louisiana and southeastern Texas. George Folkerts of Auburn University, an authority on carnivorous plants who guided me through Conecuh Forest, has noted that pitcher plants grow in eleven different kinds of wetlands—from river terraces to sphagnum mat bogs to savannas, swales, and seepage bogs. While these habitats differ in their topography and source of water, they all have an acidic soil, saturated for at least a portion of the year, and depend on periodic fires to maintain their characteristic mix of vegetation.

The pitcher plant bogs in the Conecuh National Forest are seepage bogs created by rainwater percolating down through the sandy uplands and accumulating near the bottom of slopes. In some instances, a distinct shrub swamp community is found at the very bottom of the slope, where several inches of water stand throughout the year, while the pitcher plant bogs begin a little upslope, where the soil is saturated but not flooded. Rills and rivulets of cool, clear water, most less than a foot wide, form networks throughout the bogs.

The bogs contain at least twenty different species of carnivorous plants—plants that obtain some of their nutrition from the insects they trap. These include four kinds of sundews, two butterworts, nine bladderworts, and five types of pitcher plants. In addition, the Conecuh bogs are home to a a dozen species of wild orchids and a variety of sedges, including beaked rushes.

Animal life is equally diverse. Cottonmouths often emerge from the shrub swamps to sun themselves in the open bogs. Diamond-backed rattlesnakes from the surrounding uplands frequently come to the bogs for water and then return to their drier habitat. The narrow trails used by armadillos that visit the bogs to drink can be seen. These nocturnal animals use the same trails so often that they wear them into deep ruts.

When I was in one of the bogs in April with George Folkerts, we saw a female crane fly skim just above one of the narrow rivulets and periodically dip her abdomen into the water to lay her eggs. On that spring day, caddis flies were swarming in the air. Folkerts and I paused to look at the emerging leaves of the orange macranthera, a beard-tongue-like plant. During autumn, the gorgeous orange, tube-shaped flowers of this plant open to welcome the hummingbirds that are migrating through the area.

In one of the shallow pools we saw tadpoles that would mature into pine barrens tree frogs, one of the rarest amphibians in the country. This species lives in two widely separated places, the pine barre of New Jersey and the pitcher plant bo of the Coastal Plain. Two species of fish, shiner and a madtom, also live in the ri of the pitcher plant bogs.

Pitcher plants are noted for leaves th are modified into elongated tubes, pitchers, typically hooded by their folde over tips. But these perennial plants al produce long, flat leaves and a large flow

Yellow pitcher plants are common in wetland habitats throughout the Coastal Plain.
James C. Godwin

that hangs from the tip of a leafless stalk.

Each pitcher collects water, which fills the bottom of the funnel and mixes with digestive enzymes that the plant secretes. To attract insects, the pitcher plant usually has nectar-producing glands on the hood as well as the rim of the pitcher, which often is shiny and slippery. An insect alighting on the rim tends to plummet into the watery abyss. Downward-pointing hairs that grow inside the tube prevent the victim from crawling out to safety.

The pitcher's hood is arranged in a variety of positions, depending on the species, but never in a position that blocks the entrance to the funnel. Early naturalists speculated that the hood was hinged and that it automatically sealed off the opening when an insect fell inside, but this is not the case.

The most beautiful pitcher belongs to the white-topped pitcher plant. It grows up to two feet tall, and its upper end and hood are white with conspicuous green veins. These pitchers are commonly collected and sold for floral decoration. The Office of Scientific Authority of the United States Fish and Wildlife Service issues permits for this commerce, but many pitchers are harvested illegally every year, placing the plants in jeopardy of extinction.

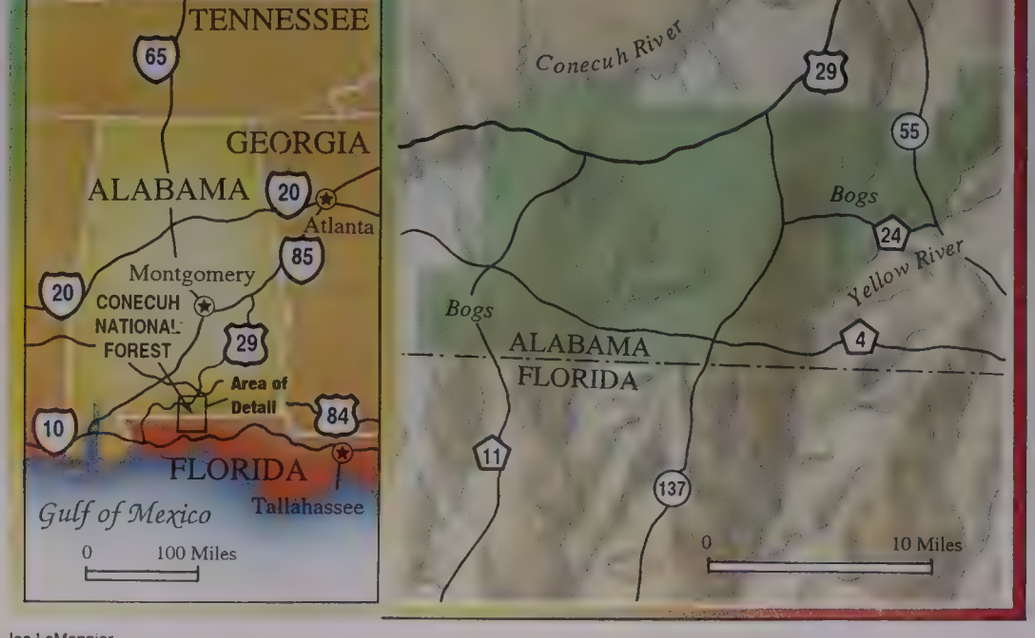
The yellow pitcher plant is probably the most common and most sturdy of them all, with bright yellow or yellow green pitchers up to two and one-half feet tall. Wherry's sweet pitcher plant has an erect pitcher usually less than one foot tall with a very short, wide, maroon-veined hood. The purple pitcher plant, the only one that is found outside of the Coastal Plain (it grows throughout the northeastern United States and westward to the Great Lakes), has a curved pitcher that more or less lies on its back. Its mouth is completely open because the hood is straight and does not arch over the tube.

The parrot pitcher plant is distinct. The variegated red-and-white pitchers are only four to eight inches tall, and the hood is an inflated structure with a pointed, beaklike tip that superficially resembles the outline of a parrot's head. In spring, the pitcher stands erect and has a broad, green finlike "wing" that extends along the front of the pitcher from the base to the hood. This structure exposes more plant surface to sunlight for photosynthesis. Pitchers that form later in the year essentially lie on their backs and lack the broad wing.

While many people think of pitcher plants as organisms that exploit insects, George Folkerts and his wife, Debbie, have found that flies, mosquitoes, and other insects utilize pitcher plants for their own survival. The larvae of the mosquito *Wyeomia,* those of a midge, and those of several species of sarcophagid flies complete their larval development in the pitcher, feeding on microorganisms and insect corpses trapped in the pitcher's fluid. As much as half the prey trapped in the pitcher may be consumed by such larvae, and this might seem to be detrimental to the pitcher plant. But George Folkerts indicates that the larvae produce large quantities of nitrogen-rich wastes, which probably nourish pitcher plants.

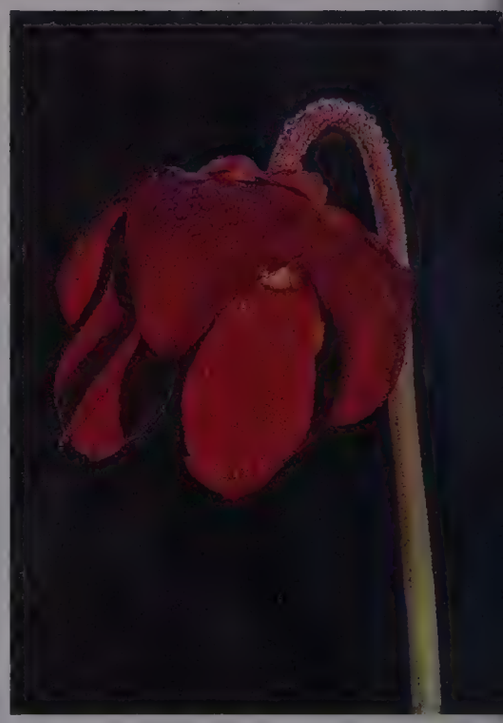
Wasps, mites, and moths also feed on the tissues of the pitchers. According to Debbie Folkerts, the pitcher plant moth spends nearly its entire life in the pitcher. In spring, the female moth lays one to several eggs on the inside wall of a newly formed pitcher. The eggs develop into larvae that girdle the pitcher with a narrow feeding channel; this causes the upper portion to wilt and topple, closing off the opening. The larvae eat only the inner tissues of the pitcher, leaving the outer epidermis intact. Shortly before pupation, the larvae cut a tiny drainage hole in the pitcher. Until the females leave to lay their eggs, adults rarely stray from the pitcher, and copulation takes place there.

The reports of early European settlers show that pitcher plant bogs were once more common in the southeastern United States. The bogs were maintained by natural fires, which were started by lightning and spread unchecked over large areas. North American Indians also burned areas to drive game and for other reasons. Such fires killed or retarded the growth of the shrubs and trees that tend to invade open bog habitats. During the 1930s, however, the United States Forest Service, with its symbol of Smoky the Bear, campaigned against fires in both forested and unforested lands. As a result, fires were not allowed to burn even in open bogs, and dozens of woody species invaded them, wiping out some and drastically reducing the size of others.



Joe LeMonnier

The blossom of a white-topped pitcher plant
Jeff Lepore



The Conecuh National Forest is not managing its bogs to preserve pitcher plants. As a result, gallberry and other shrubs, along with long-leaf and slash pine seedlings, have come up throughout the bogs. Even when the Forest Service agrees to burn, it does so during the winter, when most plants are dormant and the shrubs and trees are generally unaffected. Spring burns are needed to retard these plants (such burns do not harm pitcher plants and other herbaceous perennials, because their main food reserve is in their underground rhizomes, bulbs, and tubers). In addition, the Forest Service plants hundreds of pines in the sandy uplands above the bogs. These pines absorb most of the available water through their roots, so that little seeps downward into the bogs. Eventually the bogs dry out, and the unique flora disappears.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.

Conecuh Bogs

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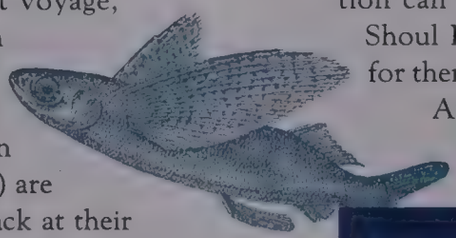
PERSPECTIVE ON THE

CARIBBEAN

By Kay Showker

any prospective visitors to the arc of islands that run from Florida to South America think first and foremost of sun, sand and sea. In recent years, however, savvy travelers have taken a fresh tack in their voyages to the Caribbean and are choosing to take a closer look into the region's multiple cultures, extensive history, and spectacular natural wonders.

As a result of the 500th anniversary of Columbus' first voyage, the Caribbean nations (Columbus' first landfall in the New World) are taking a look back at their history. The last five hundred years in the Caribbean have brought the greatest transfer of people and resources in the annals of man, creating a colorful legacy of history, cultures, and culinary delights that reflect the region's diverse origins.



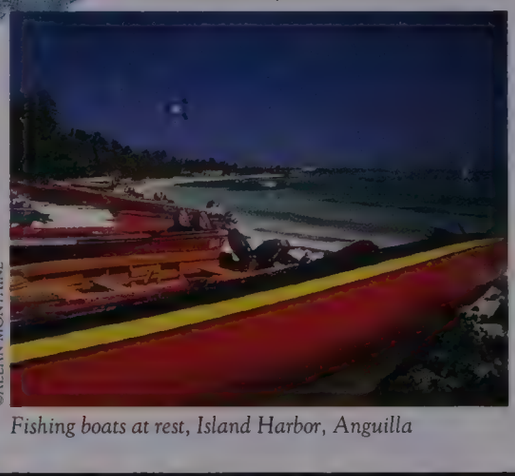
This cultural diversity is further enhanced by a backdrop of exotic natural attractions: volcanic mountains, rain forests, deserts, marshlands, and mangroves all provide sustenance and protection for a tremendous variety of sea creatures and wildlife.

Each Caribbean island is unique and offers its own compelling reason for further exploration.

ANGUILLA

Legend says that Ponce de Leon found his fabled Fountain of Youth on this small coral island five miles north of St. Martin. Weary souls seeking rejuvenation can visit the Fountain Cavern at Shoul Bay and test the magic waters for themselves.

Anguilla's varied natural attractions provide a haven for a wide array of wildlife. The north side of the island rises to a limestone ridge where visitors can see flocks of red legged stilts and white cheek pintail ducks at sunset. Two huge offshore coral reefs await snorkelers and divers who are eager to explore an underworld of sponges, sea fans, brain corals, and fish galore.



©ALLAN MONTAINE

Fishing boats at rest, Island Harbor, Anguilla

BARBADOS

Barbados was a British Colony for 300 years and has been independent since 1966, but in some ways it is still as British as the Queen. There is a Trafalgar Square (complete with a statue of Lord Nelson), be-wigged judges presiding over courts, homes and gardens in parishes named St. James, and towns called Yorkshire.

To encourage visitors to explore Barbados' historic, natural, and cultural treasures, the Barbados National Trust has created a Heritage Passport with discount vouchers to eleven sites of interest. They are as varied as the Andromeda Botanic Gardens, Morgan Lewis Sugar Mill, Gun Hill Signal Station, and the newly restored Barbados Synagogue.

A guided walking tour of Historic Bridgetown is available, as well as free

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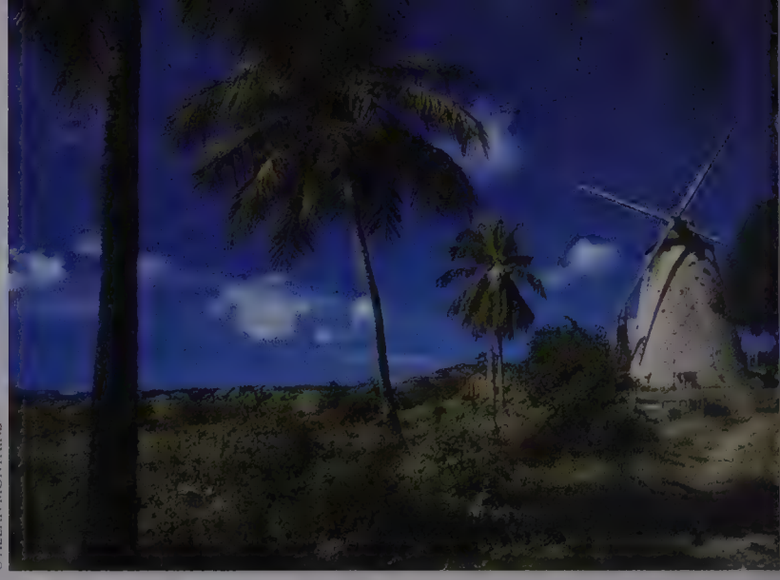
"Creole Day" on Dominica



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Morgan Lewis Sugar Mill, St. Andrews, Barbados

morning and afternoon hikes led by young Bajans and Trust members.

Barbados' cultural heritage is also showcased in two annual events: Crop Over, a two week folklore festival in mid-July, and the National Independence Festival of Creative Arts — a month of plays, ballets, concerts, and art shows.

BELIZE

The attractions in Belize are as varied and numerous as there are grains of sand on a small beach. Visitors can take in coral reefs and Mayan temples, beaches, lagoons and rain forests, the lively Caribbean resort town of San Pedro, or the considerably more rustic villages of the interior.

Belize being small (a shade larger than New Jersey) and the transportation good, it's easy to arrange an itinerary that samples a bit of everything. One company that can help organize your trip is Magnum Belize. It represents about eighty hotels, resorts and lodges throughout the country.

If you are looking for a taste of sun, sand, sea and some adventure along the coast, then the island of Ambergris Caye is the ideal destination. San Pedro (the main settlement) is filled with boutiques, rental shops, small hotels, and bars. The streets are sandy and the main form of motorized transport is by rented golf cart.

Captain Morgan's Retreat is an intimate and unpretentious resort set a little farther north on the island. It offers a tremendous variety of water experiences along the world's second largest barrier reef that runs the length of Belize.

The oldest architectural structures in the Caribbean can be found in Belize's interior, where Mayans built magnificent structures long before Columbus arrived. The ancient temple of Xuantunich in the Cayo district is still the tallest man–made edifice in the country.

"Best of Belize" offers tours of the Caracol Mayan Ruins which are three times the size of rival Tikal in Guatemala. They also offer day trips from Belize City to the Mountain Pine Ridge which features a 1,000 foot waterfall, the Cockscomb Jaguar Preserve, Lamanai Mayan ruins, and Baboon Wildlife Sanctuary.

"Best of Belize" is opening a visitors center at the Biltmore Plaza Hotel in December 1992. The center will exhibit an ongoing, narrated slide presentation of the many beautiful and exotic adventures the country has to offer.

BONAIRE

Aruba's neighbors, Bonaire and Curacao, along with St. Maarten, Saba, and St. Eustatius make-up the Netherlands Antilles. Together they share a Dutch heritage and a common language, Papiamento, a combination of Spanish, Portuguese, Dutch, and a smattering of other European words.

Bonaire is a naturalist's haven that has been preserving nature refuges, marine parks, and bird sanctuaries for years. The northern end of the island holds the Washington/Slagbaai National Park, a 13,500 acre wildlife sanctuary textured with unusual rock formations, white sand beaches, and lakes. It was also one of the first national parks established in the Caribbean.

On the flat, arid, southern end of Bonaire there is a 135 acre flamingo sanctuary, that also serves as a breeding ground for many types of birds. To introduce birders to some of the 190 indigenous species, the island held its first Bird Watching Olympics in September '92 and plans to make it a biannual event.

© CAROL LEE

Mayan stone work in the Belize interior

THE CAYMAN ISLANDS

Tucked under the western end of Cuba, the Cayman Islands are world renown as a diver's mecca. The islands' shores are surrounded by submerged mountains collectively known as the Cayman Wall. Densely encrusted with coral and other marine life, the wall attracts extraordinary displays of exotic fish.

At the mouth of the North Sound of Grand Cayman is one of the Caribbean's most unusual sites, Sting Ray City. Here, in just twelve feet of water, snorkelers and divers can touch, feed, photograph, and swim with sting rays — as many as a

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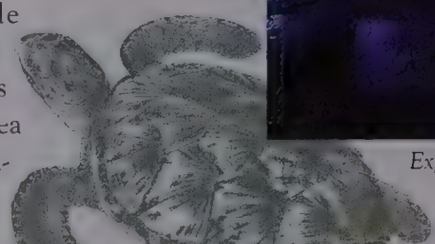
Manuel Antonio National Park, Costa Rica

dozen at a time.

Of historical interest is Pedro's Castle, the oldest standing structure in the Cayman Islands. Dating back to the 17th century, local lore claims it was Blackbeard's hideaway. The castle lies on a limestone ridge which rises twenty feet from the sea and supports many varieties of native plants.



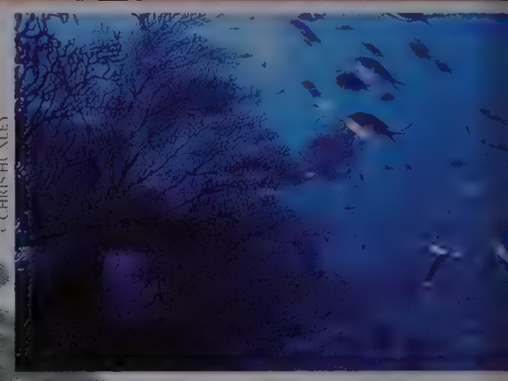
Cayman Brac is a string bean-shaped plot of untamed wilderness, which is yet to be discovered for its hiking, birding, and caving opportunities. Recently, the island got its first nature preserve — a 100 acre plot for the scarce Cayman Brac Parrot.

COSTA RICA

About the size of West Virginia, Costa Rica preserves more than twenty-five percent of its land in national parks, forestry reserves, and wildlife refuges (compared to three percent in the U.S.). Within its twelve distinct ecosystems are 1,200 varieties of orchids, more types of birds than in all of North America, and ten percent of the world's butterflies.

Santa Rosa National Park, on the Pacific Ocean, protects habitats ranging from beaches and mangroves to dry forests and wooded savannas. Area wildlife includes monkeys, anteaters, coatimundis, peccaries, and deer.

Other areas include Palo Verde National Park, a refuge for migratory waterfowl. Poas Volcano National Park, an hour and a half drive from San Jose, provides the opportunity for visitors to peer into an active volcano at 8,000 feet and



© CHRIS HALEY

Exploring the depths of St. Lucia

hike through the surrounding forest, while Tortuguero National Park protects mangroves and wildlife on the Caribbean coast.

The celebrated 4,000 acre Monteverde Cloud Forest, located in Guanacaste Province, is a private reserve that attracts international scientists to study an unusual combination of wet and dry forests. Study programs and nature tours are available for the layperson through International Expeditions (see the resource guide for more information).

DOMINICA

On this beautiful island one finds mountains, rain forests, and rivers that cascade over cliffs through valleys to the sea. These prime attractions are found in the 16,000 acre Dominica National Park — replete with magnificent scenery, four varieties of forest, and hiking trails that range from a comfortable thirty-minute stroll to a rigorous four-hour trek.

Highlights near Roseau, the capital, are the Trafalgar Falls and Freshwater Lake, the largest of Dominica's five lakes.

A cross-island highway north of Roseau winds through the mountains that skirt Dominica's best rain forests and traverses the Central Forest Reserve. En route it passes the entrance to the Emerald Falls Nature Trail, a thirty-

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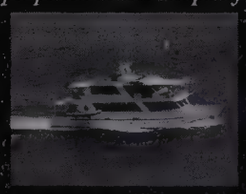

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Trafalgar Falls, Dominica

canoes, is the favorite nesting place for the Imperial parrot, one of Dominica's two endangered species.

PUERTO RICO

As proud of its Spanish heritage as it is of its American flag, Puerto Rico has launched the Columbus Quincentennial. It will continue through November 1993, the date that marks Columbus' landing on the island's shores.

Recently in Old San Juan, in front of the second oldest church in the Americas, the Plaza of the Five Centuries was inaugurated. It is part of an impressive restoration of the northwest section where some of Old San Juan's largest buildings will house the new Museum of the Americas and the relocated Institute of Puerto Rican Culture.

In Ponce, Puerto Rico's second largest town, residents are preparing for the 300th Anniversary celebration of the city's founding. The entire city has been renovated with great care to preserve its historic architecture, which ranges in style from early colonial to art deco.

Beyond the cities, the island combines scenic wonders and the geographic features of a country fifty times its size. Only thirty minutes from San Juan is the Caribbean National Forest (also known as El Yunque), which is the only tropical rain forest in the U.S. Forestry Service. It has recreation areas with well maintained hiking trails and is only one of Puerto Rico's ten forest reserves.

On the southwest coast, the Guanica Reserve hosts half of Puerto Rico's terrestrial bird species.

At the Rio Camuy Caves Park (northwest of Hatillo) you can visit caverns some as high as a two story building which are part of Puerto Rico's elaborate network of caves and tropical karst terrain. Through them flow the Camuy River, the third largest underground river in the world. Offshore, the Culebra National Wildlife Refuge protects eighty-six bird species and serves as a nesting ground for four species of endangered sea turtles. The sanctuary was established by President Theodore Roosevelt at the turn of the century.

ST. KITTS & NEVIS

To take a step back in time to a more traditional Caribbean, journey to the small, unspoiled island of Nevis in the eastern Caribbean. For those who desire elegant yet comfortable accommodations, breathtaking landscapes and rain forests filled with shy monkeys and birds, Nevis is the place for you. Downtown Charlestown is a quaint village surrounded by beautifully restored buildings, churches, and a museum.

Nestled in the mountains, high above

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The Annual Cooks Festival, Puerto Rico

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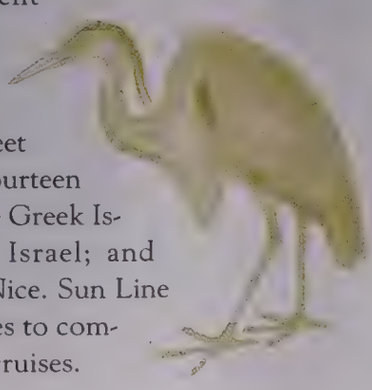
ella Solaris at anchor

The professional staff of experts also arrange adventurus trips ashore, such as jungle river expeditions, a visit to n Argentine ranch, submarine trips to coral reefs and the hance to climb the ancient Mayan ruins.

Sun Line's base remains n the Mediterranean and rom April to October the fleet ffers three, four, seven, and fourteen ay cruises from Piraeus to the Greek Isnds, Turkey, Egypt, and Israel; and round Italy from Venice to Nice. Sun Line so offers air/land/sea packages to complement these Mediterranean cruises.



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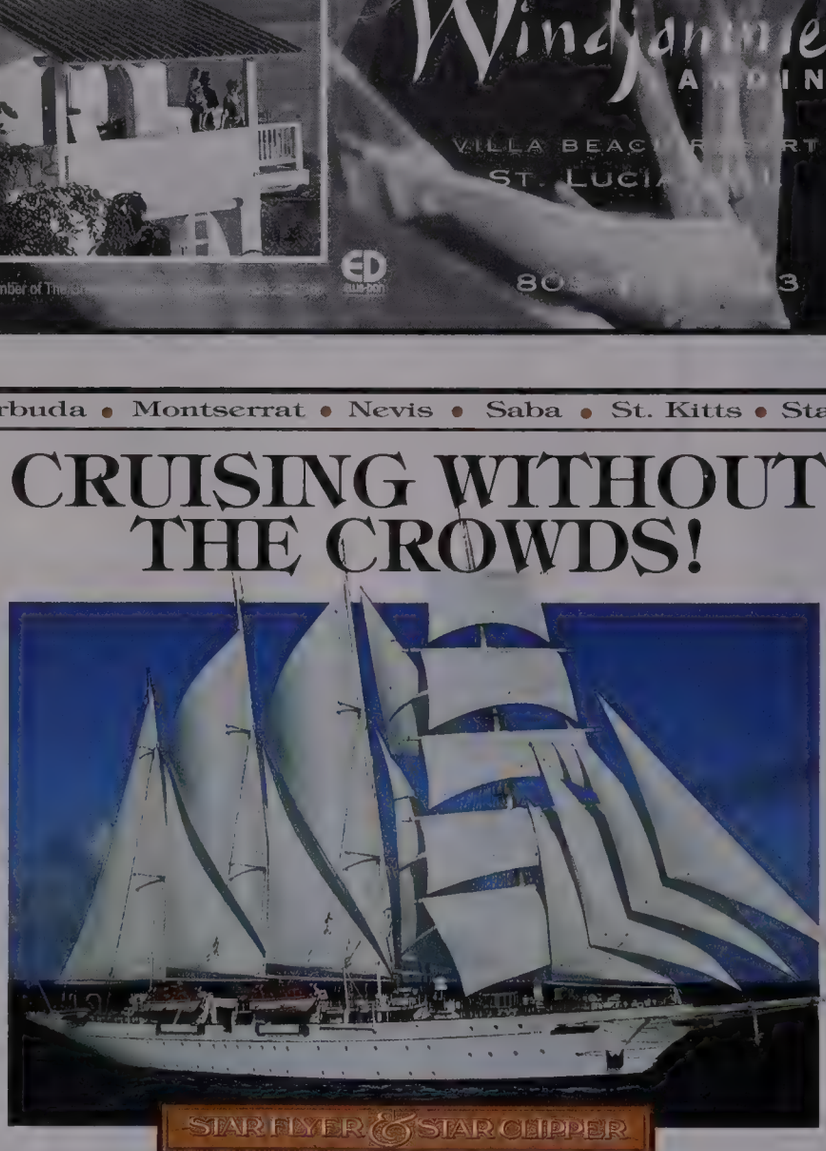

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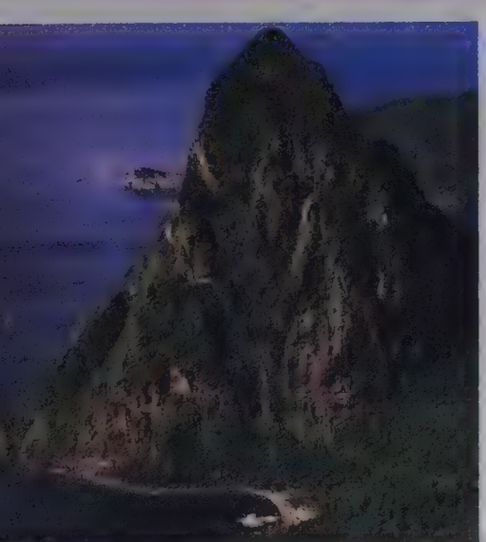

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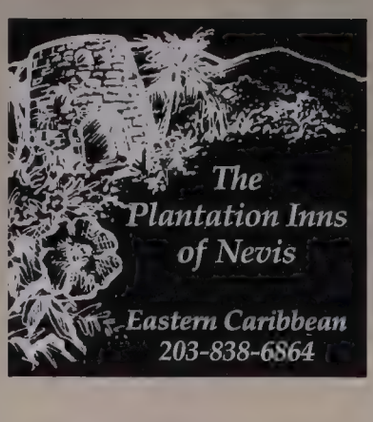
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In and Out of Flavor

ne person's meat is another's condiment

Raymond Sokolov

In ordinary language, flavor is not a ntroversial concept. We say something s flavor—is flavorful—when it has a no-ble degree of taste and smell. We register rough our mouths and noses that a par-ular food is, most often in a positive nse, tasty. The opposite of flavorful—a sh that lacks flavor—is tasteless, dull, sipid.

No normal person needs special in-uction in what we mean when we say ese things. Honorable sane adults may ffer about which dishes strike them as sty or flat, insipid or sapid (to use the arned but etymologically right anto-m), but the basic idea is clear. Some ods engage our sensory apparatus in a easant way and others don't.

The vocabulary we have inherited for s notion is an interesting (one might say asty) tangle. *Flavor* and *savor* seem to scend from the same word cluster in tin, Greek, and Old French. Dictionar-s encourage us to think that it all goes ck to Greek words meaning flavorful ids—sap or juice or gravy—on the one nd, or wise, on the other (*opos, sophos*). he Latin verb *sapio* combines both eanings. Its derived noun, *sapor,* leads raight to our savor, and its participle, *piens,* defines the human species as a owing tribe.

If this twinning of the wise and the deli-ous seems incongruous at first, one is mpted to say that there is more to gas-nomy than is contained in your philoso-y. On second thought, though, it pays to ust the language. To sapid and sapient, d the old Anglo-Saxon *pith,* which holds both sides of the question in its pithy monosyllable. In its basic botanical meaning, pith, like sap, leads us without much of a leap to other occult internal and vital fluids, notably marrow, spinal fluid, and on up to the brain.

So any discussion of flavor rests on profound questions about human intelligence and aesthetic discrimination. Flavor, we might say, resolves the mind/body split, by linking sense and sensibility.

In the kitchen, we operate instinctively in this area and rarely think much about the philosophical or semantic basis of flavor. Instead, we go ahead and do our best to see that the food we prepare has the qualities that others will recognize as flavor. There are two fundamental ways to achieve this. One is to cook basic ingredients so as to bring out their "natural" flavors. This is what Curnonsky must have meant when he prescribed that food should taste of what it was. The epitome of this approach is rare meat, fish poached only until it loses its translucence, *al dente* vegetables.

The other route to flavor requires the addition of intensely flavorful substances: salt is the exemplar here. Savory foods are salty, in English idiom. For people around the world, salt is the primary flavor additive. And it also exemplifies the aesthetic judgment so intrinsic to the notion of flavor: We salt "to taste" by using our mental sensory apparatus to make up our minds how much salt to use.

Other conventional flavorings range widely from the standard shelf of naturally occurring spices and herbs (thyme, pepper, rosemary) and aromatic substances (lemon peel, vanilla) to created concoctions (vinegar, Dijon mustard).

This is the narrow definition of flavorings. The broad definition would no doubt include almost all foods, since it is hard to think of anything we eat that does not bring its own flavor, or complex of flavors, to the table. (Soybean curd may seem like an exception to some non-Asians. A friend of mine once described a certain tofu dish as "French-fried nothing." But no aficionado of tofu would ever agree.)

At any rate, there doesn't seem much point in following this logic and classifying all foods as flavorings. If lobster is a flavoring (and it certainly has flavor), then the term becomes uselessly general. But between salt and lobster there is a midrange of foods that sometimes stand on their own as central ingredients and sometimes take on the additive, enhancing function of flavorings, narrowly defined.

Beef most of the time is a central ingredient. But beef stock, refined to the stage of classic *glacé de viande* (a highly reduced base for *haute cuisine* brown sauces) becomes a flavoring. No one would dispute that. Similarly, egg by itself is a basic ingredient of dishes such as scrambled eggs or soufflés, but egg yolk emulsified with a far greater quantity of oil (enlivened by conventional flavorings such as salt or parsley) turns into a component of a sophisticated flavoring called mayonnaise.

Perhaps you want to object that mayonnaise is often used in sufficient quantity to qualify as a central ingredient of, say, dev-

iled eggs. But it seems clear that mayonnaise, even in unhealthy amounts, is a sauce. And we might as well agree that sauces are the high-water mark of the flavoring universe. They exist to add flavor to a basic dish. (In deviled eggs, the hard-cooked eggs are the basic ingredient, but the egg yolk in the mayonnaise is not.) More to the point, sauces are never eaten by themselves (except by children; although I did once have a guest at dinner who consumed an entire boat of sauce Robert, exclaiming over the superb "soup").

Sauce as flavoring may seem altogether unriveting as a notion—especially when sauces such as ketchup are adduced—but there are several classes of flavoring/food that really are problematic, marginal item occupying an ambiguous frontier betwee the domain of main ingredients and that pure additive flavoring. In fact, they pa take of both domains.

Grain-based cuisines are rich in thes double-message foods. The typical Asia or African meal is based on rice (or som other starchy staple) but completed b lesser quantities of other foods. These ar most frequently protein foods, but in aes thetic terms they function as flavoring added to the rice or cassava or pasta. I such settings, a shrimp is still a shrimp, bu it also functions as shrimp flavoring fo rice.

Subtler still is the case of chili pepper in almost every dish where they appea The chili outsider (I have in mind, amon other types, French chefs born befor 1925) believes that chili peppers con tribute scorching heat and the preservativ power of the acid that is the medium fo the heat, but that they obscure flavor. Chil insiders know that this is a crude lumpin together of a galaxy of very differen chilies cultivated specifically not only fo their differences in size and shape an heat, but also, and crucially, for their di ferences in flavor. Chili flavors, as distinc from their heat, are, as every aficionado o Mexican or Thai food knows, the heart o the matter (or at least one of the hearts o the matter).

I was thinking about this question re cently while reading Jessica B. Harris' *Tasting Brazil,* a freshly researched cook book that opens a welcome door to th post-African (and other) dishes of demoti Brazilian cooking. She frequently spec fies malagueta peppers, which are tru chilies, but a particular variation on th overall theme and further defined, as t flavor, by the pickling medium they ofte come in. They are an important flavorin item in *molho baiano,* the sauce of th state of Bahia in Brazil's northeast. This a heavily African region in its heritage an the local sauce includes two other typica African ingredients, palm oil and smoke dried shrimp.

I suppose it requires no great leap of th imagination to see that pulverized smoke dried shrimp could function as a blata flavoring. But in Bahian sauce, even th basic oil is itself a flavoring. Palm oil, *dendê,* has a characteristic red color and a unmistakable odor, especially whe heated. This smell, which habitués love, what makes *dendê* as essential a flavorin for Brazilians as olive oil is for Italians.

Palm oil has the same double functio

Three Recipes, slightly adapted, from *Tasting Brazil; Regional Recipes and Reminiscences,* by Jessica B. Harris, Macmillan, 1992.

Banana de Terra Frita
Fried Plantain

4 large green plantains
½ cup vegetable oil
½ cup dendê *(palm oil)*
Salt

1. Peel the plantains under running water and cut them into thin rounds.
2. Mix the oils together in a heavy saucepan and heat them to 350°–375° over medium-high heat. (If you are wary of *dendê,* you can use all-vegetable oil. *However, the taste will be different* [emphasis added]).
3. Drop the plantain slices in the oil a few at a time and fry until they are golden brown. Remove the slices, drain them on paper towels, and sprinkle with salt. Serve warm.

Yield: 4 servings.

Ms. Harris writes that this Bahian specialty is "traditionally served as an accompaniment to fish dishes." When prepared with "overripe" plantains and sprinkled with sugar and ground cinnamon, the dish becomes a dessert.

Molho Baiano
Bahian Sauce

4 preserved malagueta peppers (mail order from Coisa Nossa, 46 West 46th Street, New York, NY 10036; [212] 719-4779)
Salt
2 tablespoons dried smoked shrimp (sold in Chinese markets)
1 teaspoon minced fresh ginger
2 tablespoons dendê

1. Using a mortar and pestle, pound the malagueta peppers and salt into a paste.
2. Add the dried shrimp and ginger and mash until the mixture is a thick, uniform paste.
3. Remove the paste from the mortar and place it in a heavy skillet. Add the *dendê* and slowly bring the sauce to a boil over medium heat. Serve the sauce warm in a small bowl to accompany grilled meats and Bahian specialities.

Ms. Harris writes: "In this sauce, the *dendê* is *flavored* [emphasis added] with dried smoked shrimp and malagueta peppers."

Paçoca de Carne Seca
Paçoca of dried meat

1 pound carne seca *(Brazilian beef jerky)*
½ pound fatty bacon, dried
4 medium onions, chopped
12 black peppercorns
1 pound cassava meal (sold in Hispanic markets)

1. Soak the *carne seca* in water to cover for five hours in the refrigerator, changing the water once.
2. Cut the *carne seca* into small pieces and fry them with the bacon in a large, heavy skillet over medium-high heat. Remove the meat with a slotted spoon, drain on paper towels and cook the onions in the remaining fat over medium heat, stirring, until they are golden.
3. Place the meat, onions, and peppercorns in a food processor and pulse them slowly. Gradually add the cassava meal, until you have a smooth, thick paste. If the paste becomes too thick, add a small amount of water. The *paçoca* is served with white rice.

Yield: 4 to 6 servings

Ms. Harris writes: "[*Carne seca*] is prepared by salting it and leaving it in the sun and the wind to dry thoroughly. *Carne seca* can be prepared from various types of meat, from domestic cattle to buffalo. This meat, which is also known as *charque* or *carne de sol,* is quite tough but savory, *with a distinctive taste that has no substitute* [emphasis added]."

a when it is not part of a sauce. For ex-
le, when Brazilians fry green plan-
s in palm oil, they are adding a flavor
nent that would be lost if the plantains
e fried in a flavor-neutral oil such as
oil or peanut oil.
razil also presents us with the trickiest
nese looking-glass cases: meat/meat
oring in the form of jerky—salted, air-
sun-dried meat. In Brazil, this *carne*
is an essential ingredient of the na-
al bean feast called *feijoada.* Perhaps
ago, the only meat dependably avail-
in the unrefrigerated Brazilian tropics
jerky. But today, the taste for jerky
ists only as a matter of taste prefer-
e. And in the dish called *paçoca,*
nd jerky blends with the other ingre-
ts, including cassava meal, to function
only as meat—hamburger would do
—but in a purée that is superadded to
..as a flavoring.

*mond Sokolov is a writer whose spe-
interests are the history and prepara-
of food.*

WNERSHIP STATEMENT

tatement of ownership, management, and circu-
ation (required by 39 U. S. C. 3685) of *Natural
listory,* published twelve times a year at the
merican Museum of Natural History, Central
ark West at 79th Street, New York, N.Y. 10024-
192, for October 1, 1992. General business of-
ces of the publisher are located at Central Park
Vest at 79th Street, New York, N.Y. 10024-5192.
ublisher, L. Thomas Kelly; editor, Alan P.
ernes, Central Park West at 79th Street, New
ork, N. Y. 10024-5192. Owner is the American
Iuseum of Natural History, Central Park West at
9th Street, New York, N.Y. 10024-5192. Known
ondholders, mortgagees, and other security hold-
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mount of bonds, mortgages, or other securities:
Jone. The purpose, function, and non-profit status
f this organization and the exempt status for fed-
al income tax purposes have not changed during
receding 12 months (Section 132.122, Postal
ervice Manual). The average number of copies
f each issue during the preceding 12 months are:
. Total number of copies printed: 558,421. B.
aid circulation: 1. Sales through dealers and car-
ers, street vendors, and counter sales: 4,905. 2.
Iail subscriptions: 531,115. C. Total paid circula-
on: 536,020. D. Free distribution by mail, carrier,
r other means: 10,387. E. Total distribution:
46,407. F. Copies not distributed: 1. Office use,
eftover, unaccounted, spoiled after printing:
,250. 2. Returns from news agents: 8,764. G.
otal: 558,421. The actual number of copies of
ngle issue published nearest to filing date are: A.
otal number of copies printed: 558,829. B. Paid
rculation: 1. Sales through dealers and carriers,
reet vendors, and counter sales: 4,271. 2. Mail
ubscriptions: 531,623. C. Total paid circulation:
35,894. D. Free distribution by mail, carrier, or
ther means: 10,623. E. Total distribution:
46,517. F. Copies not distributed: 1. Office use,
eftover, unaccounted, spoiled after printing:
,642. 2. Returns from news agents: 8,670. G.
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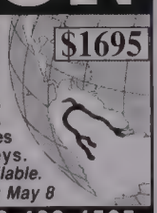

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Comet Swift-Tuttle Returns

by Gail S. Cleere

December is an eventful month for sky watchers. Comet Swift-Tuttle is returning after 130 years and a total lunar eclipse will occur on the 9th. Astronomer Brian Marsden of the Central Bureau for Astronomical Telegrams in Cambridge, Massachusetts, and others predicted that the periodic comet Swift-Tuttle (last seen in 1862) would return this year, reaching perihelion (its closest approach to the sun) in December. On September 26, 1992, Japanese astronomer Tsuruhiko Kiuchi reported the discovery of a comet in the constellation Ursa Major (the Big Bear). According to Marsden, confirmation of Kiuchi's discovery by other observers around the world leaves little doubt that the comet is Swift-Tuttle and that it is responsible for August's Perseid meteor shower (see "Celestial Events," August 1992). Calculations of its orbit show that Comet Swift-Tuttle is probably the same comet observed in China in 1737, by Jesuit priest Ignatius Kegler.

Comet Swift-Tuttle is expected to reach a magnitude of about +6.5 and will probably be visible with binoculars. Early December is the best time to try to spot it; in the evening it will be about 30° above the horizon and will then drop to about 15° toward the end of the month. At the beginning of the month, look in the southwestern skies near the tail of the constellation Aquila, the Eagle. Toward the end of the month, the comet will pass into Sagittarius and then Capricornus before rapidly disappearing into the Southern Hemisphere's skies in early January. The comet will begin another 130-year journey, going nearly twice as far as the distance to the planet Pluto, and back again.

While the comet may be sighted anytime during the month, the total lunar eclipse on the 9th will last only an hour and fourteen minutes, as the full moon moves through the earth's shadow. This is less than the maximum time possible, but as astronomer and eclipse expert Fred Espenak, of NASA's Goddard Space Flight Center, points out, "It's still ten times longer than the longest possible solar eclipse!"

The entire eclipse will be visible from Africa, Europe, and northern Asia. The beginning of the darkest portion of the eclipse—when the moon passes through the umbral shadow of the earth—will be visible in eastern and northern North America, northeastern South America, Greenland and the Arctic regions. The moon will enter the penumbral shadow of the earth at 3:55 P.M., EST, but will darken only slightly until it begins to enter the umbral shadow at 4:59 P.M., EST. Totality will begin at 6:07 P.M., EST; the middle of the eclipse will occur at 6:44 P.M., EST; and totality will end at 7:21 P.M., EST. The moon will leave the umbral shadow at 8:29 P.M., EST, and the penumbral shadow at 9:33 P.M., EST. The end of the eclipse will be visible across South and Central America and most of North America. In Washington, D.C., the moon rises at 4:35 P.M., EST, and sunset occurs at 4:46 P.M., EST. Check local newpapers for sunset and moonrise times at your location.

The umbra is the dark part of the earth's shadow; within the umbra the sun is completely blocked. The penumbra, on the other hand, is a fuzzy shadow surrounding the umbra where some light from the partially blocked sun is visible.

Lunar eclipses occur when the moon, in its orbit around our planet, lines up directly behind the earth, opposite the sun. Lunar eclipses (and solar eclipses, for that matter) do not occur every month because the moon's orbit around the earth and the earth's orbit around the sun are not on the same plane, but are tilted at a 5° angle with respect to each other. The moon's shadow therefore misses the earth during most new moons, and most full moons pa above or below earth's shadow. As a resu lunar and solar eclipses are infrequent.

Although lunar eclipses are studie only by a few professional astronome around the world today, eclipses have fa cinated and terrified mankind for ce turies. The Chinese believed a dragon w devouring the moon during lunar eclipse On more than one occasion, prior know edge of the phenomenon was used to m nipulate others. Christopher Columbu supposedly used such knowledge to mal the Jamaicans procure food for his hung crew by threatening to take away th moon if they didn't deliver.

The moon is usually still visible durin a total eclipse. As the sun's rays pa through the earth's atmosphere, red light bent, or refracted, around the planet, cau ing the moon to appear a ruddy, coppe color. In December the eclipsed moo may be unusually dark because many ra will be absorbed in the atmosphere by vo canic dust from the recent eruptions Mount Pinatubo in the Philippines.

As the sky darkens, look just to the we of the rising moon for the arrow-shape configuration of the Hyades star clust (with its tell-tale red star, Aldebaran) Taurus. Mars rises a little farther to th north just before totality ends. In th southwest, Venus and Saturn form an i teresting twosome, so all in all we hav some wonderful reasons for getting out December 9 and braving the winter col A totally eclipsed moon on our northeas ern horizon and a few planetary compa ions, plus all those brilliant winter stars the east, will decorate the sky—all at th same time. Happy holidays.

THE SOLAR SYSTEM IN DECEMBER

Mercury can be seen low in the soutl east just before dawn during most of th month, sharing the early morning ski

th Jupiter (halfway up in the south) and ars (above the western horizon). On the n, swiftly moving Mercury reaches its eatest elongation (apparent distance) est of the sun. During the week before d the week after the 9th, Mercury rises ore than one and a half hours before the n, making this the best opportunity to ot the elusive planet in 1992.

Venus, a brilliant object at –4.2 magnide, dominates the southwestern evening y all month. On the 21st, look for a close njunction of Venus with Saturn, when e two are separated by only one degree bout the width of your little finger held arm's length against the sky).

Mars rises after sunset and can be und in early December evenings in the st–northeastern skies, planted firmly in e constellation Gemini. By morning, ars is well placed above the western rizon. This month, Mars is close to, and itshines, Gemini's two bright stars, med for the Greek twins Castor and Polx (one mortal and the other not, and sons different fathers, too!). Throughout the onth, watch Mars change its position relive to those two stars as it drifts westard in retrograde motion.

Jupiter, at a prominent –1.9 magnitude, ominates the southern sky before dawn. he planet has moved out of Leo and can ow be seen against the stars of Virgo, hose brightest star, Spica, is below and to e left of Jupiter.

Saturn can be seen in the evening skies ove the southwestern horizon. On the 1st, Venus passes very close to Saturn in e sky, and on the 27th, the three-day-old escent moon forms an attractive, nearly quilateral triangle with Saturn and Venus.

Uranus and **Neptune** set soon after the n, clinging to the west–southwestern rizon just as the sky darkens.

Pluto rises before dawn not far from the irly bright star Zubeneschamali in Libra, and the nameless third-magnitude star designated SAO 140787 in Serpens. Detailed charts and a fair-sized telescope are needed to locate this faint, remote planet.

The **Moon** reaches first quarter on the 2nd at 1:17 A.M., EST; is full on the 9th at 6:41 P.M., EST: reaches last quarter on the 16th at 2:13 P.M., EST; and is new on the 23d at 7:43 P.M., EST.

The Geminid meteor shower, emanating from a point in the constellation Gemini (but seen all over the sky), peaks in the early morning hours of the 13th. This is generally the most spectacular yearly shower of "falling stars," but in 1992 the moon remains up until well after sunrise and will definitely interfere by dimming many fainter meteors. Meteor showers are generally best in the hours after midnight, when the viewer's location encounters the shower headlong because the earth is turning into the shower. However, in what may seem a heresy to meteor watchers, I advise attempting to watch the show this year before both moonrise (about 9:00 P.M., EST) and midnight. These meteors are four times denser than most, and are said to be brighter and more colorful before the midnight hour.

The winter solstice arrives at 9:43 A.M., EST, on the 21st. This marks the sun's southernmost location in the sky during the year; the sun also rises and sets at its farthest point south about this time. After the 21st, the interval of daylight for those in the Northern Hemisphere starts to lengthen, but because our coldest weather also starts now, we traditionally mark this date as the beginning of winter.

Gail S. Cleere writes on popular astronomy and is a founding member of the International Dark Sky Association, an organization dedicated to preserving the skies for astronomy.

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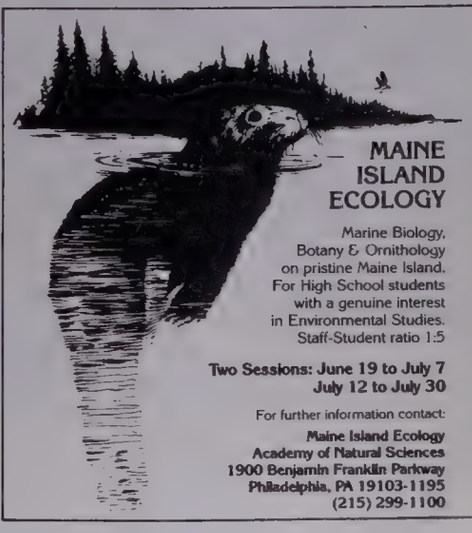

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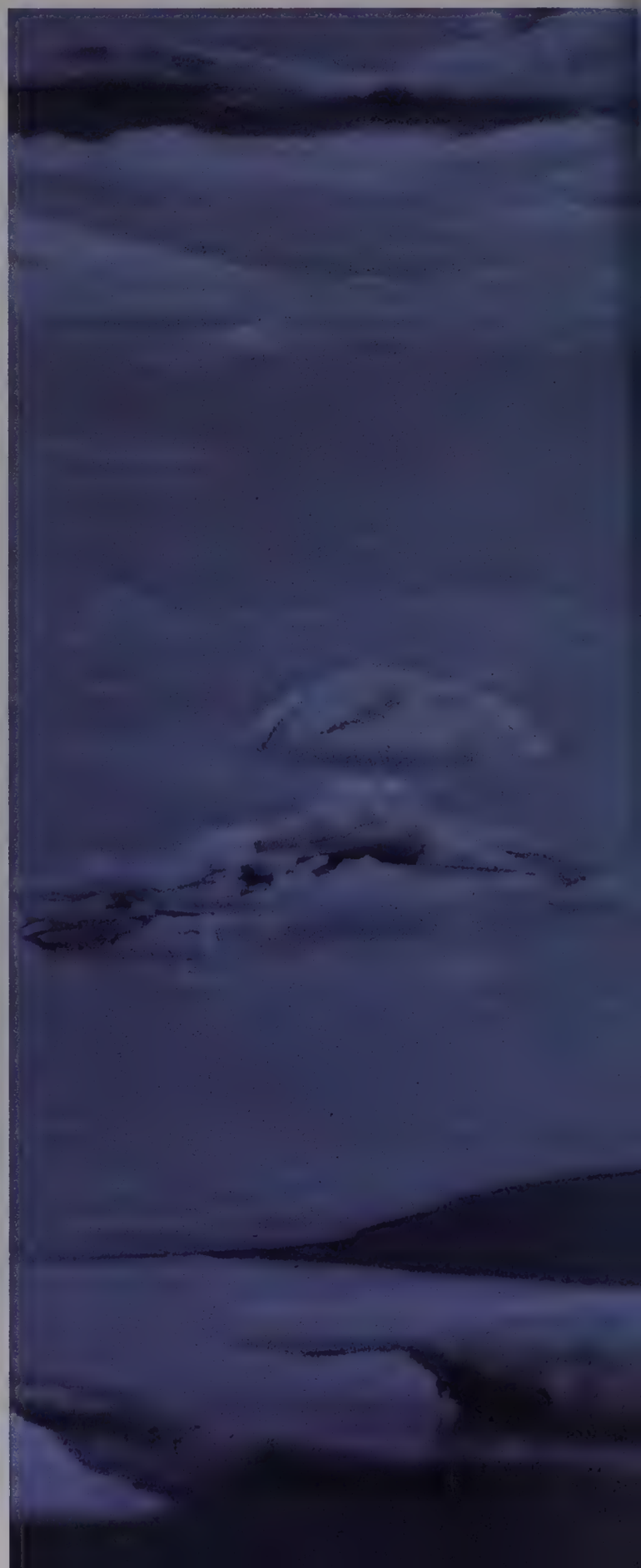

Waiting patiently at what appeared to be a seal's breathing hole, a polar bear, above, was startled when a second bear popped up instead. (Shortly before its surprise appearance, the practical joker had been swimming beneath the floe and had punched the hole through the five-inch-thick ice.) The visitor briefly rested its head on the ice, above right, and then vanished. For the next few minutes, the first bear, bewildered, sprawled on the ice, right, peering through a second hole trying to spot the other bear.

This game of hide-and-seek took place near the shore of Cape Churchill on the western edge of Canada's Hudson Bay. In late fall, hungry polar bears congregate near the cape, where the bay first freezes, waiting to hunt ringed and bearded seals on the ice. During the summer the bears survive on berries and other plants—anything edible that they can scavenge. On the ice, however, a bear only needs to kill a seal every five days or so to maintain its weight. To ambush a seal, a bear often stands motionless for hours next to a breathing hole. If a seal emerges, the bear will lunge, snatch the seal's head with its jaws, and jerk the animal up through the hole, killing it almost instantly. Polar bears also swim underwater to approach seals resting on floes and then burst out of the water to make their kills.—*R. A.*

Photographs by Dan Guravich

At the American Museum of Natural History

Origami Holiday Tree

The Museum's twentieth annual Origami Holiday Tree is on display in the Roosevelt Memorial Hall from Monday, November 23, to Monday, January 11. The fifteen-foot tree is decorated with 1,500 folded-paper animals, including new insect and dinosaur models created by origami enthusiasts from Italy, Spain, Japan, and the United States. Three thousand silver-paper stars provide the tree with a glittering halo, and around the tree's base, the four seasons are represented in habitat dioramas.

"This Is the American Earth"

Celebrating the Sierra Club's centennial, "This Is the American Earth" presents more than fifty black-and-white photographs of the American wilderness by Ansel Adams, Eliot Porter, Edward Weston, Minor White, Philip Hyde, William Garnett, Pirkle Jones, and other photographers. Accompanying the images is text in blank verse by Nancy Newhall, the late photography writer and critic. The exhibition opens Tuesday, December 1, in the Museum's Akeley Gallery and runs through Sunday, January 24, 1993.

Contact: Cultural Change, Alternative Perspectives

In conjunction with the quincentennial celebration of European contact with the Americas, the Education Department offers free programs that examine indigenous and non-European cultures after contact.

Among the presentations are: African-derived music and dance forms of Puerto Rico—*bomba* and *plena*—by Los Pleneros de la 21; rural and urban dance styles by the Foot and Fiddle Dance Company; folktales of the African diaspora; and storytelling through dance by the Pretty Flower Dancers (Blackfeet/Narragansett). These programs are made possible in part by gifts from the Vidda Foundation, the Samuel and May Rudin Foundation, and the family of Frederick H. Leonhardt. For a program, call (212) 769-5315.

Kwanzaa

Kwanzaa (Swahili for "first fruits of the harvest") is a unique African American holiday, which is celebrated from Saturday, December 26, through Friday, January 1. On Sunday, December 27, a traditional African village market will be set up in the Museum's Akeley Hall of African Mammals, Hall of Ocean Life, and Hall of Invertebrates. On Monday and Tuesday, December 28 and 29, various performances, lecture-demonstrations, and participatory workshops relating Kwanzaa themes and celebrating cultures of the African diaspora, will take place in the Charles A. Dana Education Wing. For further information and a brochure, call (212) 769-5315.

Destination Moon

Brian Sullivan, the Hayden Planetarium's production designer, will host *Destination Moon,* the second presention in the classic science-fiction film series. Produced in 1950, this classic, starring Warner Anderson and John Archer, depicts an imaginary trip to the moon nearly two decades before moon landings became a reality. The program will be held at the Kaufmann Theater on Saturday, December 5, at 3:00 P.M. Tickets are $7 ($4 for members). Call (212) 769-5606 for ticket information.

Captioned Exhibits

To make its exhibits accessible to the hearing impaired, the American Museum of Natural History will caption all of its current and future video exhibits. Two currently captioned videos, "Speak Out: The Rap on Global Warming" and "Wildlife's Uncertain Future," are included in the exhibition "Global Warming: Understanding the Forecast," on view through Tuesday, January 19, 1993. Captioning will also be added to all videos in the Museum's permanent exhibit halls, to the future Hall of Human Biology and Evolution, and to the reconstructed dinosaur and mammal fossil halls.

Star of Christmas

Planetarium visitors will travel back nearly 2,000 years to explore the skies of the first Christmas, when the Wise Men followed the special star that led them to Bethlehem. The holiday Sky Show, "Star of Christmas," begins Wednesday, November 25, and runs through Sunday, January 3. Tickets are $5 for adults, $2.50 for children ($4, $2 for members). Call (212) 769-5920 for information.

On Wednesday and Thursday, December 9 and 10, at 7:30 P.M., the Ensemble for Early Music will perform a concert of medieval music. Tickets are $15 ($12 for members). For details, call (212) 769-5900.

These events take place at the American Museum of Natural History, located on Central Park West at 79th Street in New York City. The Kaufmann Theater is located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more Museum information call (212) 769-5100.

"Aspens, northern New Mexico, 1958," *by Ansel Adams, a photograph in the exhibition, "This Is the American Earth"*

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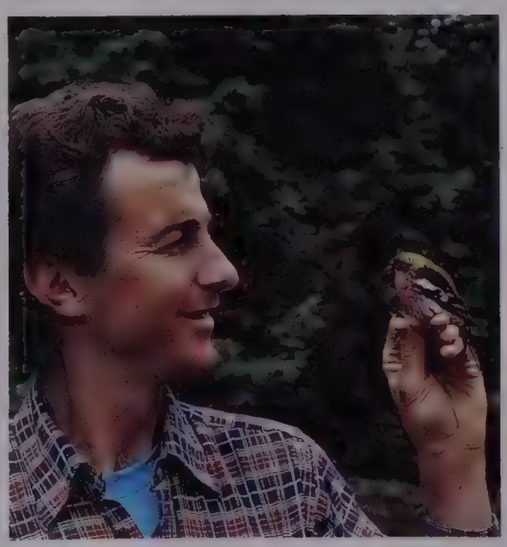
Asked why he went into medicine and
at prompted him to work in Peru, **War-**
n M. Hern (page 30) points to his par-
s, "who had a strong social conscious-
ss," and his admiration for Albert
nweitzer, whose biography he read in
ior high. Hern, a native Kansan, was
ught up in Englewood, Colorado, and
ned his B.A. and M.D. from the Uni-
sity of Colorado in the 1960s. His ten
nts in Peru since 1964 have led to a
rong emotional connection" with the
pibo Indians and a heightened concern
h public health and population issues.
rn went on to get a masters degree in
blic health and a Ph.D. in epidemiology
l is now an associate professor adjunct
anthropology at the University of Col-
do, Boulder. He continues to divide his
e between a medical practice in Boul-
and his continuing studies of the health
ects of cultural and ecological change
ong the Shipibo. His work has been
pported in part by the Wenner-Gren
undation for Anthropological Research.
commended books are *The Upper*
azon, by Donald W. Lathrap (New
rk: Praeger, 1970), and *Yanomamö: The*
rce People, by Napoleon A. Chagnon,
l ed. (New York: Holt Rinehart and
nston, 1983).

For the past nine years, **Craig Benk-man** (page 38) has been as nomadic as the crossbills he studies—traveling from Alaska to Newfoundland in search of crops of conifer seeds. In 1987, while a postdoctoral fellow at Princeton University, he went to Newfoundland looking for white-winged crossbills and came across the strange situation of the peculiar, sedentary subspecies of red crossbill native to that island. Now a lecturer in environmental studies at the University of California at Santa Cruz, Benkman plans to study a red crossbill subspecies of western North America that is specially adapted to feed on seeds of Sitka spruce. He also intends to apply his findings on Newfoundland crossbills to birds on other "islands," such as ecologically isolated areas of the Great Basin. Benkman enjoys hiking and exploring the countryside while searching for good crossbill habitats. A stint working on a purse seining boat along the coast of Alaska last summer allowed him to sight-



see and also identify future study sites. For more on these birds, Benkman refers readers to *Pine Crossbills,* by Desmond Nethersold-Thompson, (Vermillion: Harrell Books, 1975), a natural history of another island population, the Scottish crossbill. Stuart L. Pimm's *The Balance of Nature?* (Chicago: University of Chicago Press, 1991) discusses interactions among species and conservation issues.

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"At a Morgan Library exhibition twenty years ago, I saw one of Maria Sibylla Merian's watercolors, and what impressed me was that in 1699 a fifty-two-year-old woman would go off to South America to paint insects," says **Sharon D. Valiant** (page 46). Her initially casual interest in the artist has grown into an all-engrossing effort to untangle the many threads of Merian's story. In the course of her research, Valiant has amassed a large collection of books about Merian, as well as books on the development of science in the seventeenth century. Valiant, who has a master's degree from East Tennessee State University in history and library science, taught for many years but now designs needlework and crafts to support her rare-book collecting and historical sleuthing. For Merian fans, she recommends: David Freedberg's "Science, Commerce, and Art" in *Art in History, History in Art,* D. Freedberg and Jan de Vries, eds. (Chicago: University of Chicago Press, 1991); and Elisabeth Rucker's and William T. Stern's *Maria Sibylla Merian in Surinam* (London: Pion Ltd., 1982).

While filming "Seasons in the Sea" for the television series "Nature," **Howard Hall** (page 26) found himself swimming amid a school of giant jellyfish of an unknown species. Hall and his crew spent three years producing the film, which was shot in the ocean off southern and central California. After receiving a B.S. degree in marine zoology from San Diego State University, Hall turned his interest in ocean life into a career by specializing in underwater photography. He has also produced two films, "Seasons" and "Shadows in a Desert Sea," that focus on marine life in Mexico's Sea of Cortez and is currently producing one on the Caribbean. In addition to his underwater life, Hall also enjoys hang gliding, skiing, and hiking. The wide-angle photographs of the jellyfish were taken with a Nikonos camera, 15mm lens. Close-ups were taken with a Nikon 8008, 60mm lens.

Standing on the ice pack in the Beaufort Sea, **Dan Guravich** (page 84) cradles a polar bear pup to keep it calm while its mother is anesthetized for routine tagging. Guravich, who lives in Greenville, Mississippi, earned a Ph.D. in biology in 1949 and then worked in Greenville on cotton genetics for a few years before switching to a career as a free-lance photographer. He became interested in polar bears in 1969, when he sailed on board the S.S. *Manhattan*—a supertanker that was traveling from the Atlantic Ocean to Point Barrow, Alaska, and back again, to test the feasibility of the Northwest Passage fo transporting oil in pre-Alaska-pipelin days. In July, Guravich often makes th trek to Wager Bay, which is north of Huc son Bay, to photograph polar bears. In No vember he rejoins the migrating bears Cape Churchill, where he photographe this month's "Natural Moment" after sev eral hours of watching five bears play o the thin ice. He used a Minolta Maxxum equipped with an 80–200mm zoom len His upcoming book on these animals wi be published by Chronicle Press in Jun 1993.

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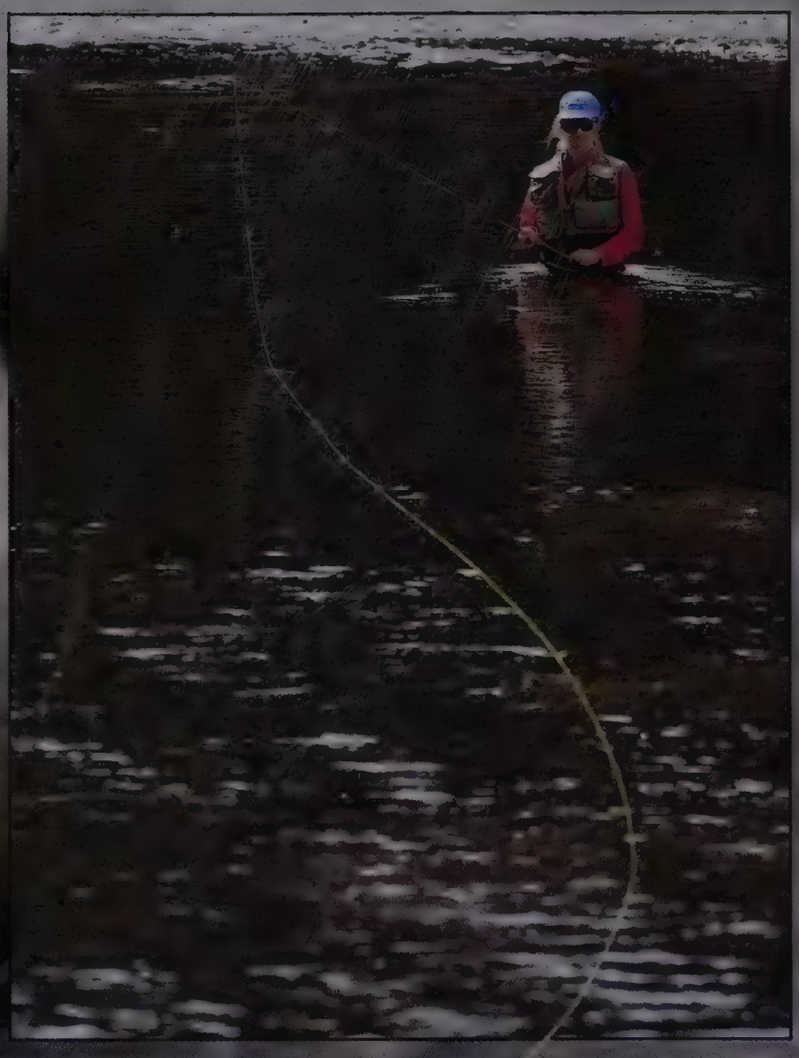

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